COMBUSTION

MAY 2 1936

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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This furnace at the Port Washington Station is over 55 ft wide, 24½ ft long, and has a total volume of 73,000 cu ft.

Trends in Design of Large High-Pressure High-Temperature Boiler Units

Determining Oxygen in Boiler Feedwater

New Boiler Plant Effects Savings at Wathen Distillery

HEAT RECOVERY

NUMBER THREE

. . . of a series of advertisements in which subjects of current interest to utility engineers and consultants are briefly reviewed and present trends indicated. Subjects to be covered are listed below but deviations may be made either in sequence of list or titles.

Superposition • Furnace Design

Heat Recovery • Heat Cycles

Boilers for High Pressures and Temperatures

Availability of Modern Boiler Units

THE available heat in fuel, as determined by complete combustion in a calorimeter, includes the latent heat of evaporation of moisture. With heat value thus determined, the maximum overall efficiency which can be economically attained by modern steam generating units is in the range of 85 to 90 per cent.

Although a steam generating unit with its associated heat recovery equipment may be compared to a fuel calorimeter, it cannot be commercially designed to give equal efficiency. This is so because the heat loss due to production of steam from moisture in the fuel and from the combustion of hydrogen is unavoidable. With bituminous coal this may amount to 4 per cent or more, and with oil to over 7 per cent.

By using the lower or net heat value of fuel, as is done in European practice, the above-mentioned efficiency range would be of the order of 89 to 94 per cent. The differences between these figures and 100 indicate the practical magnitude of the combined combustion, radiation and sensible heat losses. Only the last of these can be further reduced by "heat recovery" in the ordinary sense of the term, that is, by the use of an air preheater, an economizer or both.

Fifteen years ago air preheaters were virtually nonexistent in American practice and such economizers as had been installed were of the now obsolete cast-iron construction. Today it is common practice to include either an air preheater or a steel-tube economizer or both in all steam generating units of moderate size or larger. As a result, average efficiencies have increased 5 to 15 per cent.

With operating pressures above 600 lb, boiler exit gas temperatures of well over 700 F at normal load are common. Very often, depending upon the type of boiler, the most economical overall design may result in boiler exit temperatures above 900 F. In neither case would an economizer alone be able to reduce the gas temperature to the minimum practical point (about 350 F at normal load) with the feedwater temperatures generally encountered. With economizer feedwater at 300 F, the economic minimum gas temperature would be about 500 F and an air preheater also would be required. Except in stoker installations, the best practice is to install a larger air preheater than would be necessary to effect the 200 deg gas drop and to use only sufficient economizer surface to accomplish the required gas drop between the boiler and the largest size air preheater that can be economically installed.

For stoker-fired units in cases where only moderately high efficiency can be justified, an economizer alone is generally more economical due to the limitation of stokers with respect to preheated air temperature. Where high efficiency can be justified, air preheater as well as economizer surface is required.

Many variables are involved in the determination of minimum economic gas temperature leaving the air preheater, some of which are: cost of fuel; kind of fuel; load factor; range of load variation; minimum winter air temperatures; importance of availability; ease of replacement of surface; cost of replacement of surface, etc. Determining that proportion of boiler, air preheater and economizer surface which will give optimum results in any given case is accomplished by experimental evaluations of different combinations until the most economical one can be established. The wide variation in the conditions governing each case make this procedure the only practical one. It requires skilled analysis predicated upon extensive experience and the availability of considerable performance data.

Maximum obtainable efficiencies in the neighborhood of 90 per cent can be economically justified for conditions of base load operation with high load factor and fairly high fuel cost. For average conditions, maximum economic efficiency is in the range of 84 to 87 per cent.

A major limiting factor in heat recovery is the necessity of keeping final gas temperatures high enough to prevent corrosion of heating surfaces. Although the dew-point of water vapor in the gases may be as low as 120 F, if oxides of sulphur are present an exit gas temperature of about 350 F may be necessary to avoid condensation of acid and consequent corrosion. Even where the use of corrosion-resisting metal can be economically justified, there still remains an operating problem due to the presence of liquid which accelerates ash accumulation. A point of importance in this connection is that the metal temperature may control condensation of acid. Dirty areas on heating surfaces can cause a gas film to stay in contact with the metal long enough to reduce the local gas temperature to the dew-point even though the average gas temperature leaving the equipment may be well above that point. With air preheaters it is sometimes practical to recirculate a portion of the heated air at low ratings to prevent corrosion.

To avoid internal corrosion in economizer tubes, the use of a deaerating heater is necessary. This results in feedwater temperature entering the economizer at 212 F or higher. Since the minimum practical temperature difference between gas leaving an economizer and entering feedwater is about 200 F, it is therefore not possible to reduce exit gas temperature with an economizer alone below about 400 F.

As has been indicated, it is possible today to obtain overall efficiencies, calculated on the more practical lower or net heat value, of 90 to 94 per cent. Therefore it may be said that no appreciable improvement is possible until the sulphur content of coal can be removed before burning, or until materials capable of resisting corrosive sulphur compounds become economically available.

COMBUSTION ENGINEERING COMPANY, INC.

200 MADISON AVENUE • NEW YORK

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SEVEN NUMBER ELEVEN

CONTENTS

FOR MAY 1936

FEATURE ARTICLES

Trends in Design of Large High-Pressure High-Temperature Boiler Units	*by F. H. Rosencrants*	*16*
Modernizing the Conners Creek Power Plant—VII	*by Sabin Crocker*	*23*
Determining Oxygen in Boiler Feedwater	*by A. C. Dresher*	*33*
Boilermaker as an Employee within Workmen's Compensation Statutes	*by Leslie Childs*	*35*
New Boiler Plant Effects Savings at Wathen Distillery	*by E. B. Rodman*	*37*
Application of Colloidal Chemistry to Boiler Water Conditioning	*by L. Drew Betz and Robert T. Sheen*	*39*

EDITORIALS

Support for Research 15
Treated Coal vs. Performance 15
Out-Moded Terms 15

DEPARTMENTS

Steam Engineering Abroad *42*
Review of New Books *44*
Advertisers in This Issue *48*

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ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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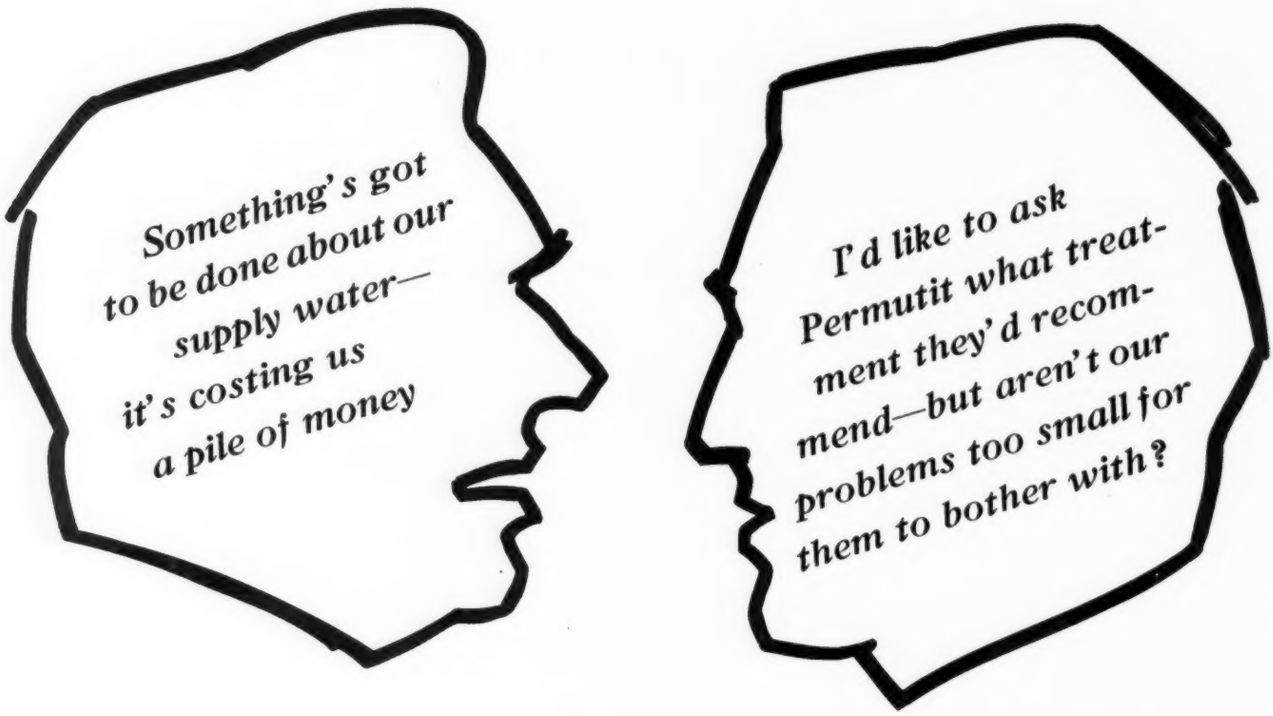
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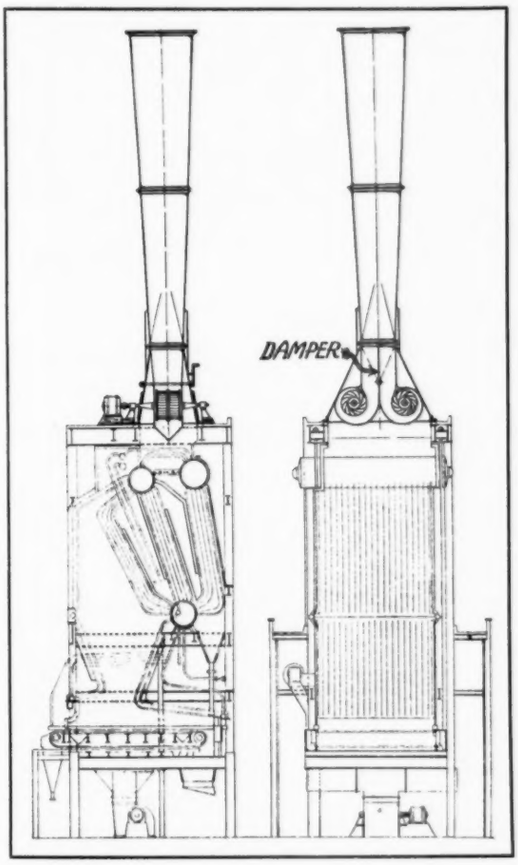

Installs a

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TWIN-FAN STACK

Designed to Save Power

Capacity: 205,800 cfm gas, at 8.3″ Static Pressure

Engineering Facts of Interest to You

Boilers are usually designed for a maximum greater than the normal operating load. Fans are customarily designed to give an additional safety factor on gas quantity and draft of 20% to 30% more than this. Fan horsepower increases as the cube of the boiler loading. In other words, theoretically, at 70% of maximum safety load on a boiler, a fan should consume $\frac{70^3}{100^3}$, or only 34.3% as much power as at maximum load.

The Thermix Twin-Fan Stack is designed with two fans and two drives, each with half the maximum required horsepower. Over 90% of the time only one fan and drive is operated. The result is less power input, better motor or turbine efficiency—and a spare fan to boot for normal rating. The fans are interconnected (an important feature) and Thermix Stacks are equipped with a specially designed outlet damper—a more efficient arrangement than ordinary inlet dampers.

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The Unit Responsibility Idea

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This is a special cast alloy blade $^5/_8$″ thick at the surface of greatest wear, held on the underblade without rivets or welds. It may be renewed with two or three hours' labor, and the rebladed wheel does not have to be removed nor rebalanced. This has been described as one of the most important advances in induced draft fan practice in a decade.

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Florida Power & Light Co., Sanford, Fla.
Jersey Central Power & Light Co., South Amboy, N. J.
National Light & Power Co., Moose Jaw, Sask.
Stamford Gas & Electric Co., Stamford, Conn.
Borough of Quakertown Central Station, Quakertown, Pa.
University of Chicago, Blackstone Power Station
Virginia Public Service Co., Bremo Bluff, Va.

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DETERMINING CHEMICAL REQUIREMI

FOR illustrating this subject, three water supplies with widely divergent qualities were selected. The first involved a well water with the following characteristics:

TABLE I ANALYSIS OF WELL WATER

		(Gr. per U. S. Gal)
Temporary hardness	($CaCO_3$)	21.4
Permanent hardness	($CaCO_3$)	26.0
Total dissolved solids		79.7
Suspended matter		7.6
Calcium bicarbonate	($CaCO_3$)	13.7
Magnesium bicarbonate	($MgCO_3$)	6.5
Sodium bicarbonate	($NaHCO_3$)	nil
Calcium sulphate	($CaSO_4$)	17.3
Magnesium sulphate	($MgSO_4$)	15.4
Sodium sulphate	(Na_2SO_4)	23.2
Calcium chloride	($CaCl_2$)	nil
Magnesium chloride	($MgCl_2$)	nil
Sodium chloride	(NaCl)	1.8
Iron and alumina	(R_2O_3)	.12
Silica	(SiO_2)	1.77

This supply was to be used for cooling purposes in process operations. Because of the large quantity of calcium and magnesium carbonate and bicarbonate that this contained, with resulting heavy precipitations over the cooling surfaces, such a supply would be highly undesirable, if not correctly conditioned through chemical treatments prior to its use for the specific purpose mentioned.

The results of such conditioning in an experimental laboratory setup are reflected in Table II

TABLE II

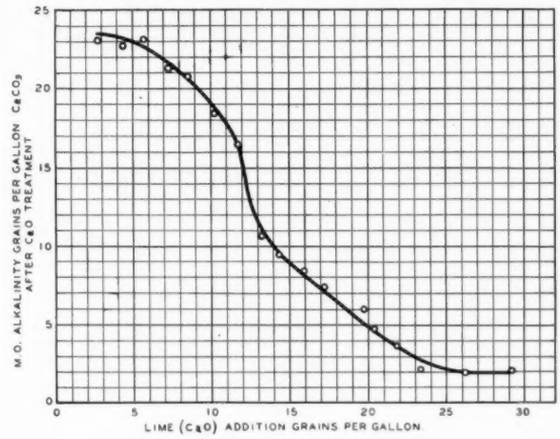
No	Time	Quick Lime gr/gal	Pht. Alk. gr/gal $CaCO_3$	M.O. Alk. gr/gal $CaCO_3$	CaO terms $CaCO_3$ gr per gal	MgO terms $CaCO_3$ gr per gal	Effectiveness in %	Suspended Matter gr/gal
1	19 hr	2.9	0.0	23.2	26.7	21.3	..	.03
2	" "	4.4	0.0	22.9	29.2	20.9	..	.09
3	" "	5.8	0.0	23.2	28.1	21.3	..	.09
4	" "	7.3	0.0	21.3	25.8	21.8	.5	.10
5	" "	8.6	0.0	20.9	24.7	19.7	2.3	.13
6	" "	10.2	0.0	18.3	24.9	21.2	15.0	.13
7	" "	11.6	0.0	16.6	21.9	19.4	22.4	.13
8	" "	13.1	0.0	10.7	21.2	19.2	44.7	.15
9	" "	14.5	0.0	9.5	20.1	19.8	47.7	.23
10	" "	16.0	0.0	8.4	18.9	15.6	62.3	.12
11	" "	17.4	0.0	7.4	18.1	17.6	66.8	.20
12	" "	19.9	.6	6.0	16.8	16.2	73.4	.29
13	" "	20.3	.7	4.9	15.6	17.8	77.6	.26
14	" "	21.8	1.4	3.7	15.2	19.6	84.2	.18
15	" "	23.3	1.4	2.2	15.0	18.3	91.2	.18
16	" "	26.2	1.4	2.0	14.6	13.4	92.2	.7
17	" "	29.1	1.2	2.1	14.2	13.4	88.2	.20

The quantity of lime needed to bring about the maximum reduction of these carbonates and bicarbonates approximated 23 gr per gal. Column 8, Table II, shows the effectiveness of this dosing to be better than 90 per cent. Curve I pictures this same result while Curve 2 shows the chemical reactions in this case to have been completed in about an hour in each of the experiments and the clarification of all samples with turbidity at zero to have taken place within three hours.

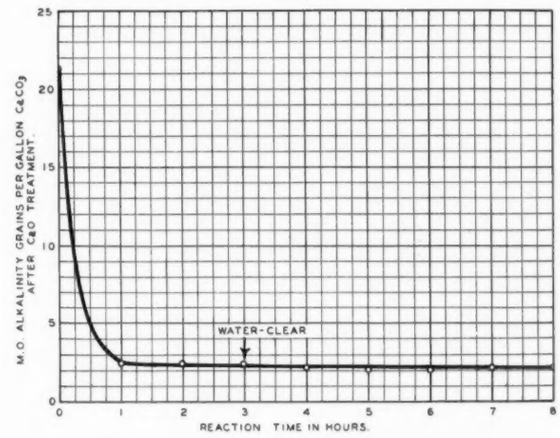
To study further the effectiveness of this lime treatment for the specific purpose under advisement the product of the treatment was concentrated ten times with only a noticeable precipitation on the cooling coils. As the average water concentrations in the cooling towers are usually less than this number and lime-treated waters are sand-filtered before use, the product developed through the laboratory experiments should prove satisfactory under normal plant conditions.

Another fact developed in this work, and which confirms the results under plant conditions, is the comparatively small percentage of active reducing constituents which the lime contains and which function in the removal of the carbonates and bicarbonates. This approximated 60 to 65 per cent in this setup, although the lime in use carried better than 90 per cent available calcium oxide.

THE second example in these experiments involved the use of a colored water for process work at a paper mill. The analysis of this is given under Table III.



Curve 1—Relation of lime addition and reduction of alkalinity.



Curve 2—Velocity of the alkalinity reduction.

TABLE III ANALYSIS OF RAW WATER

		(Gr per U. S. Gal)
Temporary hardness	($CaCO_3$)	4.41
Permanent hardness	($CaCO_3$)	12.59
Pht. alkalinity	($CaCO_3$)	nil
M.O. alkalinity	($CaCO_3$)	4.41
Total dissolved solids		69.86
Suspended matter		0.65
Calcium bicarbonate	($CaCO_3$)	4.41
Magnesium bicarbonate	($MgCO_3$)	nil
Sodium bicarbonate	($NaHCO_3$)	nil
Calcium sulphate	($CaSO_4$)	2.84
Magnesium sulphate	($MgSO_4$)	6.50
Sodium sulphate	(Na_2SO_4)	nil
Calcium chloride	($CaCl_2$)	nil
Magnesium chloride	($MgCl_2$)	4.80
Sodium chloride	(NaCl)	51.00
Silica	(SiO_2)	0.25
Iron and alumina	(R_2O_3)	0.06
Sulphides, terms H_2S		2.00
pH		6.9

The turbidity, suspended matter and color requirements in this instance had to be very low. Laboratory experiments were, therefore, carried out with these objectives in view. Low treating costs were also not to be ignored here. The final result of this work proved that a treatment of lime-ferrous sulphate would deliver a satisfactory product.

Other important conclusions developed in this same way showed the necessity for maintaining a pH of 10 and of applying the lime considerably ahead of the ferrous sulphate in the softener operation. An hour's time was needed in this case for the maximum chemical reactions.

E MENTS FOR INDUSTRIAL WATERS

The results of the experiments for this application, together with the costs, are given in Table IV.

TABLE IV EXPERIMENTAL DATA

Treatment (Expressed in gr per gal) Lime	Caustic Soda	Ferrous Sulphate	Pht. (Terms	M.O. $CaCO_3$)	pH	Color	Suspended Matter	Cost per 2,500,000 gal
10	0	2	0.0	3.3	7.3	exceeds 70	3.1	$18.50
11	0	2	0.1	2.2	7.6	exceeds 70	4.0	19.97
12	0	2	0.9	2.3	9.3	exceeds 70	3.7	21.37
13	0	2	2.0	3.0	10.3	1	.23	22.79
14	0	2	2.8	3.7	10.5	1	.27	24.21
10	0	5	0.0	2.4	7.7	exceeds 70	3.7	24.90
11	0	5	0.1	2.7	7.8	exceeds 70	3.2	26.32
12	0	5	0.4	2.0	8.4	exceeds 70	3.8	27.74
13	0	5	0.5	1.7	9.1	exceeds 70	3.0	29.16
14	0	5	1.5	2.4	10.1	2	.18	30.58
12	4.5	2	2.1	3.7	10.2	1	1.6	61.52
6.5	9.3	2	5.4	9.8	10.4	1	.31	104.37
7.0	10.0	2	5.8	10.4	10.5	1	.27	110.87

THE third study in this setup involved the conditioning of a water for boiler feed purposes. The analysis of the supply on this is reported in Table V.

TABLE V ANALYSIS OF RAW WATER

		(Gr per U. S. Gal)
Temporary hardness	($CaCO_3$)	2.90
Permanent hardness	($CaCO_3$)	4.84
Pht. alkalinity	($CaCO_3$)	...
M.O. alkalinity	($CaCO_3$)	...
Total dissolved solids		14.27
Suspended matter		trace
Calcium bicarbonate	($CaCO_3$)	2.90
Magnesium bicarbonate	($MgCO_3$)	nil
Sodium bicarbonate	($NaHCO_3$)	nil
Calcium carbonate	($CaCO_3$)	nil
Magnesium carbonate	($MgCO_3$)	nil
Sodium carbonate	($NaHCO_3$)	nil
Sodium hydroxide	(NaOH)	nil
Calcium sulphate	($CaSO_4$)	3.80
Magnesium sulphate	($MgSO_4$)	2.44
Sodium sulphate	(Na_2SO_4)	1.68
Calcium chloride	($CaCl_2$)	nil
Magnesium chloride	($MgCl_2$)	nil
Sodium chloride	(NaCl)	3.00
Silica	(SiO_2)	0.33
Iron and alumina	(R_2O_3)	0.12
pH		7.3

Here, with an intermittent softener in operation, treating temperatures near 125 F and a 7-hr period for the chemical reactions, the results were very unsatisfactory as measured by the softener product and internal boiler conditions. In this case a supplemental addition of sodium aluminate to the existing soda ash-lime treatment overcame the troubles at the minimum expense.

TABLE VI

				After 7 hr at 120–130 F		After 20 hr, 7 of which were at 120–130 F and remainder at room temperture				
Sample No.	Lime	Soda Ash	Sodium Aluminate	Pht. (terms	M.O. $CaCO_3$)	Pht. (terms	M.O. $CaCO_3$)	CaO as $CaCO_3$	MgO as $CaCO_3$	Total Hardness $CaCO_3$
13	2.24	6.89	1.0	1.4	3.2	1.2	3.2	0.21	0.05	0.26
15	2.44	6.89	1.0	1.0	3.0	1.1	2.9	0.31	0.05	0.37
17	2.63	6.89	1.0	1.8	3.1	1.8	3.0	0.42	0.10	0.52
19	2.82	6.89	1.0	1.9	3.1	1.9	3.0	0.42	0.10	0.52
14	2.24	6.89	0.0	1.3	3.7	1.3	3.7	0.31	1.05	1.36
16	2.44	6.89	0.0	1.3	3.2	1.3	3.2	0.52	0.92	1.44
18	2.63	6.89	0.0	2.0	3.4	2.0	3.3	0.63	0.89	1.52
20	2.82	6.89	0.0	2.3	3.2	2.2	3.2	0.57	0.89	1.46

Table VI shows the results of experiments which were carried out for determining the treatment limits best suited for this conditioning. In this case the calcium and magnesium remaining in the finished treated water, according to gravimetric determinations, was 0.26 gr per gal for Sample No. 13. A rate of 1.0 gr per gal of sodium aluminate was used in this connection and a Phenolphthalein alkalinity of 1.4 and a Methyl Orange reading of 3.2 was maintained. With the sodium aluminate excluded and the same lime and soda ash treatment rate in effect, this hardness in the finished treated water reported for sample No. 14 was 1.36 gr. or four times that contained in Sample No. 13.

These experiments in which the alkalinity limits are guides for controlling the results in the field apply to a specific water and operating condition. They have no other application. This is true because one rarely finds two treating combinations alike as to water characteristics, treating temperatures and operating conditions. While this is the case, the characteristics of a specific industrial water supply change very little in the relations existing between those of its constituents which influence the lime and soda treatments in softener operations, and which in turn determine the Phenolphthalein and Methyl Orange alkalinity readings that are necessary to hold, if the lowest hardness is to be maintained in the finished waters.

For illustration, assume the total water constituents to receive a lime and soda treatment approximates 15 grams per gallon of which 5 grams or one-third is carbonate hardness and 5 grams or one-third is magnesium hardness, then this same supply when diluted through rains and condensate additions to 12 grams, will carry near 4 grams carbonate hardness and about 4 magnesium hardness, or the same one-third relation as existed in the more concentrated supply.

Within recent years the accuracy of the various indicator practices in use for water treatment control purposes has been questioned but in the setup discussed above the Phenolphthalein and Methyl Orange alkalinity limits to be carried are based on a known effect, and as the same indicators are used in the plant the effect in the finished treated water is the same as in the experiments and is relative to this, regardless of any individual indicator inaccuracies as these are based on the more definite laboratory procedures.

Where facts in this way can be either charted or tabulated in some simple form, they do furnish the easiest and most accurate means available today for controlling treatments through external water softener operations and actually find practical application for better than 80 per cent of the industrial water supplies.

Once determined for a specific water, they certainly reduce errors in dosing to the possible minimum. Again, with such regulations available there is no excuse for using "hit or miss" practices for controlling treatments and very much less reason for employing chemicals of unknown value and effect. In any event, there is no legitimate reason for the existence of unsatisfactory chemical treatments of boiler feedwaters, either internally or through water softeners.

This statement may, also, include the elimination of unsatisfactory sludge conditions. Resulting through these same softener operations, especially in view of our existing knowledge of colloids and effects they do have in keeping boilers free of any accumulations of this type.

RICECALOID, the more recent development of the Rice Laboratories, is especially effective in this connection for waters in which silica is not a problem because of the very small quantity required to eliminate sludge as a troublesome factor in boiler operations.

PHOSCALOID, again because of its high P_2O_5 content and combined colloids proves very effective in the same connection as an after-treatment, where silica proves troublesome.

Cyrus Wm Rice, *President*

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STURTEVANT INDUCED DRAFT FANS CHOSEN FOR 165,000 K.W. ADDITION

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Showing two of four Sturtevant Turbovane Induced Draft Fans, each rated 190,000 c.f.m., recently installed for 165,000 k.w. addition to Richmond Station of Philadelphia Electric Company. Addition designed and constructed by United Engineers and Constructors, Inc. in cooperation with engineers of Philadelphia Electric Company.

HIGH EFFICIENCY, reliable operation and rugged construction were the most essential requirements in selecting equipment...when Philadelphia Electric Company recently doubled the capacity of their Richmond Station. 165,000 K.W. capacity was installed in space originally provided to accommodate 50,000!

For induced draft, primary air, and pulverized coal mill service, the engineers chose 12 Sturtevant Turbovane Fans.

The four Sturtevant self-cleaning Induced Draft Fans are each rated 190,000 c.f.m. at 380°F. against 14.5 static pressure. Speed: 850 R.P.M. They serve two new Babcock & Wilcox 600,000 lb. per hour pulverized-coal-fired boilers.

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EDITORIAL

Support for Research

When one considers the extent to which the taxpayers' money is being squandered on non-productive projects and various forms of so-called "boon-doggle," it is in order to speculate as to the benefits that might accrue to the present and future generations were even a small part of this stupendous sum diverted to fundamental research. The Government's only contribution to such effort lies in the meager appropriations for the maintenance of certain long-established public agencies, which have done creditable work within the limits of their facilities, but which usually experience difficulty in securing the funds necessary to carry on routine studies. It may be argued that such expenditures would not put many to work. This is quite true as concerns the present, but the potentialities offered for future economic gain and the welfare of society are far-reaching.

In this country most research has been carried on by private companies, endowed foundations and educational institutions, many of which are far better equipped, through experience and trained personnel, to handle such problems than would be possible by any hastily constituted governmental body. While relatively few large industrials are in a position to carry on fundamental research, as distinguished from development work, one could hardly expect public support to private industrial research. However, with the universities the situation is different and they might very properly be assisted in their research by Federal aid just as the experiment stations of some universities now receive state aid. The same might also apply to certain endowed institutions.

The problems susceptible to fundamental research are numerous and comprise many fields, including public health and engineering. To mention one, H. H. Lowry in a paper before the A.I.M.M.E. last winter pointed out that the coal bill of the country is probably more than one and one-half billion dollars a year. If fundamental research in combustion, carbonization and hydrogenation brought about an increase of only one per cent in the national fuel economy, the saving to the public would amount to fifteen million dollars a year. It would not seem unreasonable to spend a million dollars a year on a well-planned continuing program in which the best scientific talent should be employed. The money would be well spent.

Even in normal times, it is regarded quite within the province of governmental activity to engage in studies directed toward the conservation of natural resources and some work of this nature has been carried on. At the present time when vast sums are being appropriated for various other purposes it is reasonable to suggest that such work be extended and broadened. If it is in order for the Federal Government to subsidize farming, shipping and the distribution of electricity, directly or indirectly, research certainly has a valid claim to its share.

Treated Coal vs. Performance

Some months ago reference was made editorially to the increasing use of dust-treated coal, particularly that which is sprayed with oil. At that time it was observed that the primary objective of minimizing dust by conglomerating the fines and more or less coating the larger pieces was undoubtedly worth the slight additional cost of about five cents per ton, but that it was still a question whether there was any appreciable effect on combustion.

Since then the practice has continued to spread and there are now about forty mines that are spraying with oil. Moreover, some of the larger power companies are becoming interested in ascertaining just what there may be in it from the standpoint of improved performance, and some preliminary tests have been made. While these have not been complete enough to afford definite information, they have in some instances, with underfeed stokers, indicated that ignition is improved and that the efficiency is increased due to reduced cinder loss. In one case the quantity of cinders collected from the uptake was found to be about two-thirds that obtained when burning untreated coal under like conditions; also that the cinders weighed appreciably less per cubic foot, thus indicating less unburned carbon.

From eight-tenths to a pound of oil per ton appears to give the best results. When this amount was doubled the fuel bed with an underfeed stoker became packed and required excessive draft. Conversely, for a given draft and the proper amount of oil a somewhat thinner fuel bed could be carried.

The results of the more complete tests now contemplated will be awaited with interest.

Out-Moded Terms

Notwithstanding that the term, "boiler horsepower," is both obsolete and meaningless, it still persists to a surprising extent in power plant vernacular. Some have attempted to get away from the term by substituting "square feet of boiler heating surface," on the assumption that ten square feet of heating surface is equivalent to a boiler horsepower. However, modern trend in boiler practice toward less surface in the boiler proper and more in the water walls, superheater and heat-recovery equipment, has rendered this substitute equally absurd. To cite a typical case now in the construction stage, the boiler heating surface is 3500 sq ft, equivalent to 350 hp, yet the unit will produce 300,000 lb of steam per hour.

While heat output in "million Btu per hour" is the most correct measure of capacity, and is employed by many large companies, the term "thousand pounds of steam per hour," although less accurate, is being used more and more even for smaller units. Furthermore it ties in directly with the steam requirements of the prime mover.

If we are to discard boiler horsepower why not also drop square feet of boiler heating surface?

Trends in Design of Large High-Pressure High-Temperature Boiler Units*

By F. H. ROSENCRANTS, Vice President,
Combustion Engineering Company, Inc.

Large boiler units built and now operating represent the best thought of their designers eighteen months or more ago and an instance in which a designing engineer would repeat, in all details a design now executed and operating, would be infrequent. Existing units therefore are of interest primarily to the extent that the successful or unsatisfactory functioning of their various features is exerting an influence on the minds of engineers who have designs in hand or contemplated for the immediate future. At such time as the boiler units herein referred to have been finished and placed in operation they will be primarily of interest only to the extent that their operation is a factor influencing current design. By delaying publication of designs until they have become operating actualities, such publication is from one to two years behind current thought on the subject. In the following presentation no unit described, with the exception of the Port Washington unit, has yet operated. In many instances they have progressed no further than the general arrangement drawings. They are, therefore, as nearly as it is possible to make them up to date with current thought.

ECONOMIC developments in the construction of boiler drums for high pressure, the increasing demand for high and controlled steam temperature, and the desirability of obtaining a high steam output per foot of furnace width are among important factors influencing the design trends of large, high-pressure, high-temperature boiler units. Other factors are: the continued developments in pulverized fuel and stoker firing, water cooling of furnaces, steam washers and the advance in the science of feedwater treatment.

Drum Construction

The adoption of forged-steel construction for the cross-drum, sectional-header, straight-tube, 1200-lb pressure boiler installed in the Edgar Station of the Edison Electric Illuminating Company of Boston in 1925, followed by the bent-tube multi-drum 1390-lb pressure boiler having drums of similar construction and installed in the Lakeside Station of the Milwaukee Electric Railway and Light Company in 1926, pioneered the way for high-pressure construction for these types of boiler.

The handicap suffered by the multi-drum design in total drum weight is offset, to a large extent, by the cost of the forged sinuous headers of the cross-drum sectional-header design. That the two were approximately competitive is borne out by the considerable number of both types which have been installed.

The Committee of the A. S. M. E. Code for Power Boilers adopted rules for forged boiler drums in July 1927. These rules were revised in July 1929. Two classes of steel were included: Class I, having a tensile strength of 60,000 lb per sq in., and Class II, having a tensile strength of 75,000 lb per sq in. Most drums in service are made of Class II steel. The Code rules required the drum heads to be forged as an integral part of the drum. The cost of labor and material in the formation of these heads was often nearly as much as the cost of the entire cylindrical portion.

The Boiler Code Committee adopted rules for the construction of electric fusion-welded drums in July 1931. These rules limited the tensile strength of the steel to a value between 55,000 and 65,000 lb per sq in. with design calculations based on 55,000 lb. In August 1934 the Committee adopted specifications increasing the tensile strength of the steel and permitting drum calculations based on 70,000 lb for plate of moderate thickness and 65,000 lb for the heaviest plate.

In October 1934, a concession was made in the rules governing the construction of forged-steel drums which permitted formed drum heads to be welded to the ends of forged cylinders.

Throughout this development, specifications, until very recently, permitted the use of carbon steel only. The cost of material per pound has, therefore, been but little affected. From a brief review of the successive steps enumerated, it will be appreciated that in each instance the cost of construction has been decreased. In some instances, the decrease has been substantial. The development has therefore been a factor in promoting the economic position of high-pressure steam. It has also been a factor in improving the competitive position of the multi-drum bent-tube design.

As recently as February of this year (1936) the Boiler Code Committee approved the use of low-carbon steel

* From a paper presented at the Midwest Power Engineering Conference, Chicago, Ill., on April 23, 1936.

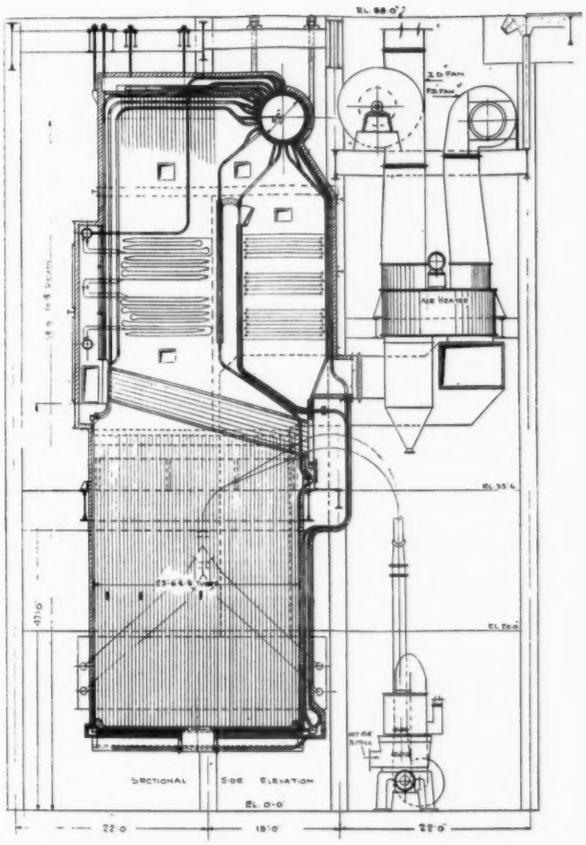


Fig. 1—Approximate cross-section of 500,000 lb per hr, 1400-lb pressure, 900-deg steam temperature units on contract for Waterside Station of the New York Edison Co.

alloyed with from 0.25 to 0.60 per cent of molybdenum. This small amount of molybdenum, among other things, has the effect of increasing the ductility and the yield point, and also results in a plate which may be more readily bent to cylindrical form. The material cost is, however, somewhat increased.

The limit of thickness for welded construction is set by the thickness of plate which can be accurately formed by cold bending. Drums of carbon steel having a thickness slightly over four inches have been in service over two years. The cross drums for the 1400-lb boilers on order for the Waterside Station of the New York Edison Company will be 60 in. internal diameter and have a shell thickness approximately $4^{3}/_{4}$ in. The 54-in. drums for the 1425-lb pressure boiler on order for the Appalachian Electric Power Company to be installed at Logan, West Virginia, will have a shell thickness of $3^{29}/_{32}$ in. The 48-in. drums for this boiler will be $4^{5}/_{16}$ in. thick. These drums will be of welded construction and low-carbon molybdenum steel will be employed.

Thus far the field of alloy steel for drum construction has been touched only to the extent above referred to. There are, of course, no considerations of temperature requiring material other than carbon steel. It is not impossible, however, that economic considerations may lead to further developments in the use of alloy material.

Superheaters

In the present era of high-steam temperature, the superheater has ceased to be merely an accessory to a boiler. It has become a major item and a dominant factor influencing the arrangement and extent of heating surface in the unit as a whole. Physically, it frequently has more surface than the boiler, absorbs more heat than the boiler and costs more. The service stresses imposed upon tubes and supporting structure are infinitely more severe than on the boiler. The success of the unit as a whole, very readily may be a matter of superheater design and details. Present-day superheater construction merits a high degree of discriminating consideration on the part of engineers responsible for the purchase of new equipment.

Figs. 1 and 2 show, respectively, the general arrangements of units on order for the New York Edison Company's Waterside No. 2 Station and a high-pressure design of the bent-tube type. They are not presented as representing standard arrangements of their particular types. There is no such thing. They are, however, of interest in representing a current trend of thought and will serve for reference in comments to follow.

In Fig. 1, the arrangement of superheating surface permits a close approximation to counterflow of steam and products of combustion. In Fig. 2 the products of combustion flow parallel to the superheater tubes and the relationship between the flow of steam and products of combustion lies intermediate between counter and parallel flow. For Fig. 1, the gas temperature leaving the superheater may be reduced to a value within 300 deg of the saturated steam temperature, whereas in Fig. 2 this leaving temperature must be something higher than the final superheated steam temperature. For practical

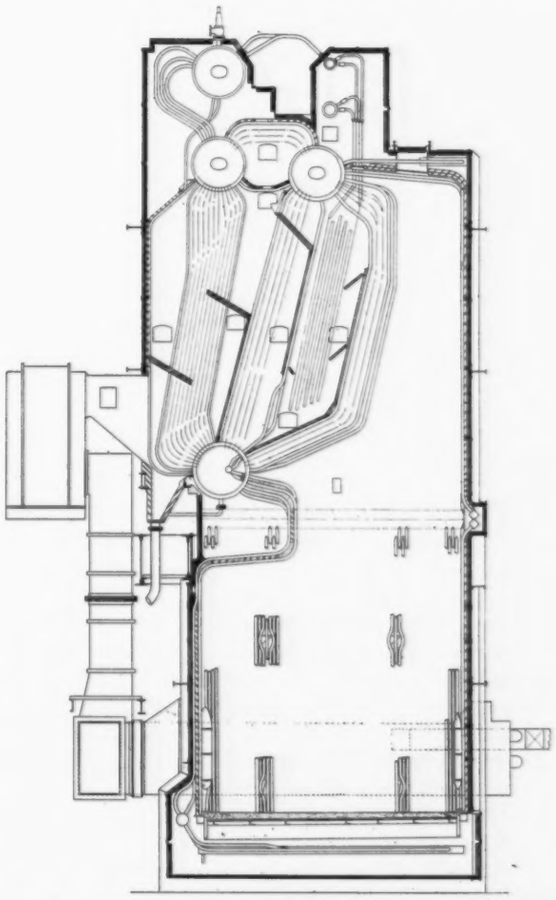


Fig. 2—Approximate cross-section of a large capacity, 925-lb pressure, 835-deg steam temperature unit of the bent-tube type

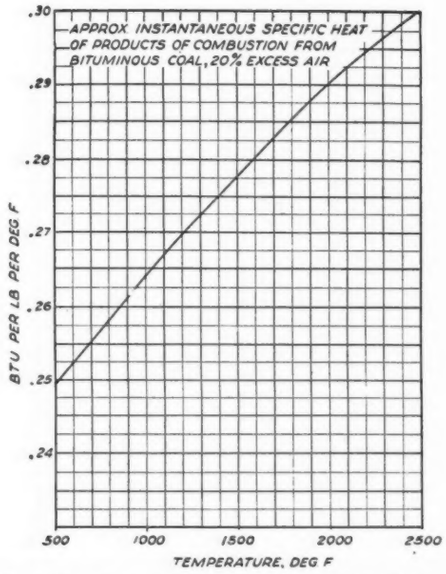


Fig. 3—Variation in specific heat of products of combustion with temperature

design it has been found that it should be at least 150 deg higher.

Figs. 3, 4, 5, 6 and 7 form the basis of an interesting study concerning the important zone in the temperature scale occupied by the superheater. The extent to which interchange of radiant heat to and from the superheater, delayed combustion, variation in temperature over the section of gas flow, etc., affect performance have been ignored. In specific instances, however, these factors might become important.

Fig. 3 showing the relationship between temperature and specific heat of the products of combustion is inserted as a matter of record and information. Values from this curve were used in calculating the temperature drop across the superheater indicated in Figs. 5 and 6. Excess air to the extent of 25 per cent has also been assumed.

Fig. 4 is of interest in that it conveys a conception of the relative amounts of heat absorbed by the different classifications of heating surface making up the pressure parts. The allocation to the boiler and water walls, with a completely water-cooled furnace, will be absorbed to the extent of 60 to 80 per cent by water walls. With this in mind, the heat absorbed by the superheater relative to that absorbed by the boiler becomes impressive.

Fig. 5 applies to the condition of steam and gas flow for the superheater arrangement associated with Fig. 1. In suggesting a differential temperature of 300 deg between inlet steam and outlet gas, it is to be understood that this represents an approach to the minimum differential for practical design. To the extent that this may be increased without resulting in a furnace outlet temperature exceeding the fusion temperature of the ash the mean temperature difference between steam and gas may be increased. The surface in the superheater may be correspondingly reduced.

Fig. 6 applies to the condition of steam and gas flow for the superheater arrangement associated with Fig. 2. As previously stated, the gas temperature out of the superheater must be higher than the final superheat temperature by a practical minimum of approximately 150 deg.

A drop in temperature, by convection, across the radiant heat protective screen between furnace and superheater will be a minimum of approximately 200 deg for Fig. 1 and 150 deg for Fig. 2.

Comparison of the furnace outlet temperatures for Figs. 1 and 2 indicates the advantage of the counterflow arrangement where a low furnace outlet temperature is desirable. For 900-deg steam, minimum furnace temperatures do not become excessive for either arrangement. For 1000-deg steam, however, the minimum furnace outlet temperature for Fig. 2 is approaching the fusion temperature of the ash for much of the coal in common use and exceeds such temperature for most midwestern coals. The superheater is becoming pinched between maximum permissible furnace outlet temperature and the practical minimum temperature at the superheater outlet.

In those cases wherein full steam temperature is required at some reduced rating, the temperatures indicated in Figs. 5 and 6 apply at such rating. Temperatures, including furnace outlet temperature, at the maximum rating will be higher. How much higher depends on a number of factors, some of which vary with the physical design of the specific installation. Fig. 7 is typical for fully water-cooled furnaces. From it an idea may be gained of the magnitude of increase in furnace outlet temperature between any point of rating at which full superheat is required and the maximum rating.

Keeping in mind the elementary requirement that, to avoid troublesome slag formation, the furnace leaving temperature must be below the fusion temperature of the ash, it will be apparent that superheat requirements, very easily and innocently, may be specified that cannot be fulfilled satisfactorily from an operating point of view. With full knowledge of the limitation involved, however, it may be good judgment to make an economic compromise with the best operating conditions. For exam-

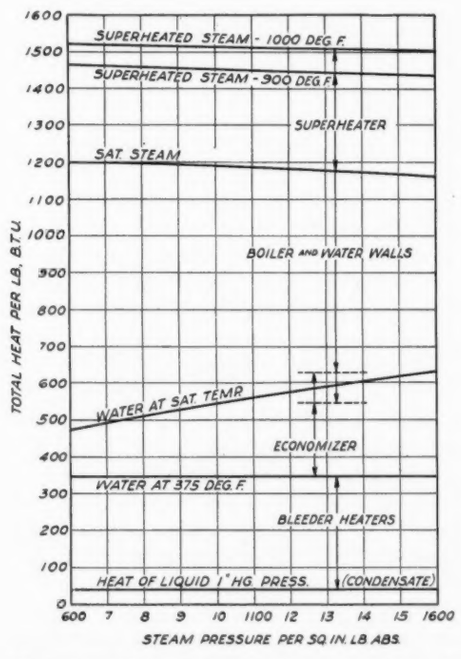


Fig. 4—Allocation of heat absorption to various classes of high-pressure, heat-absorbing equipment for pressures of 600 to 1600 lb per sq in.

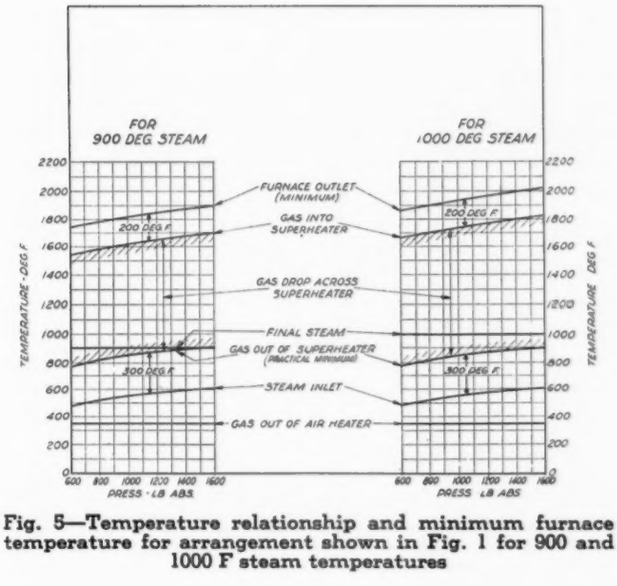


Fig. 5—Temperature relationship and minimum furnace temperature for arrangement shown in Fig. 1 for 900 and 1000 F steam temperatures

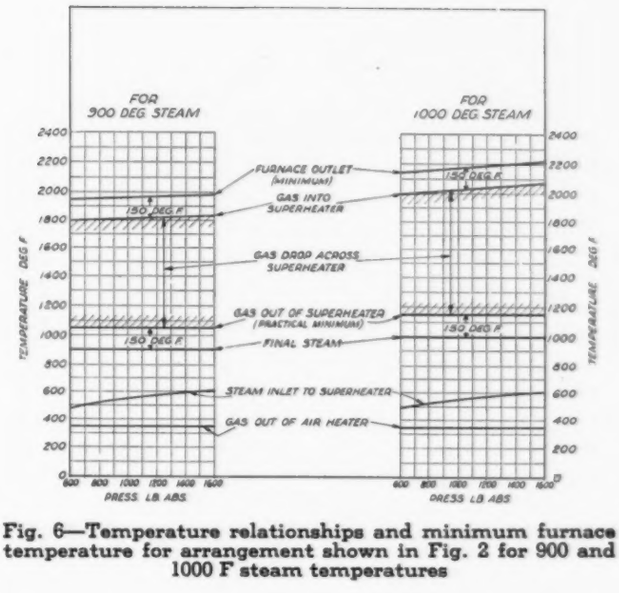


Fig. 6—Temperature relationships and minimum furnace temperature for arrangement shown in Fig. 2 for 900 and 1000 F steam temperatures

ple, with a mid-western coal having an ash of a very low fusing temperature, a furnace outlet temperature at peak ratings slightly in excess of such fusion temperature, coupled with adequate facilities for removing slag from the heating surfaces, may be fully justified.

Superheat in any given installation is a function of a number of factors—some fixed, some variable. Of the latter, the rate of steam output, excess air and cleanliness of waterwall, boiler and superheater surfaces are collectively of sufficient influence to demand an antidote, particularly for extremely high steam temperatures—first, because protection must be afforded equipment exposed by design to a temperature closely approaching the limit which it will withstand; and second, because of the inherent sensitivity of high-temperature superheaters to a change in gas temperature. This latter point is illustrated by Fig. 8. Here it will be seen that for the high steam temperature condition noted the arithmetical mean temperature difference is 701 deg and for the low it is 970 deg—a ratio of 1 to 1.37. That is to say, the high-temperature superheater response to a change in gas temperature is 37 per cent greater than is that of the low-temperature unit.

Of the several means proposed for controlling final steam temperature the scheme of controlling the flow of gas over the superheater by some form of bypass and damper arrangement has already become the accepted standard.[1] High-temperature metals, similar to those used in the superheater supporting structure, are available for damper construction. Little sacrifice in arrangement is necessary or justified to get the damper in a specially cool atmosphere. The operation of the damper in all cases is made automatic in response to variation in steam temperature.

Boiler, economizer and air heater surface may be used, within their limitations, separately or collectively, for absorbing the residual heat in the products of combustion leaving the superheater. Considerable latitude is permissible in working out the most economical arrangement. Boiler heating surface alone is never sufficient for efficient results. With a saturated steam temperature well above 500 F an outlet gas temperature of something over 650 F would be the practical minimum. Economizer surface alone will seldom be sufficient. The entrance feedwater temperature will be, in practically all cases, well over 300 F and may be in excess of 400 F. With a minimum excess temperature of gas outlet over that of water inlet of 150 deg the final gas temperature will be from 450 to 550 F, or more. To bring the final gas temperature to a value below 450 F an air heater is an essential element of equipment. It is conceivable that an air heater alone would be equal to the total task, as is indicated later; actually, however, it must be supplemented with boiler or economizer surface to obtain an acceptable overall performance.

For high-pressure, high-temperature units rated at high capacity per foot of furnace width, boiler surface beyond the superheater for the arrangement shown in Fig. 1 may be dismissed from consideration. First, because such surface is expensive and the amount of heat which could be absorbed is at best small; second, because natural circulation in horizontal tubes at this elevation in the setting is likely to be defective.[2] For the arrangement indicated in Fig. 2, however, a reasonable differential exists between boiler-water temperature (saturated steam) and gas temperature. For the lower part, at least, of the pressure range under discussion, small additional cost is involved in adapting the boiler

[1] See "Regulation of Steam Temperature by Controlled Gas Flow—The Compensating Superheater," Part I, E. V. Rieder, Detroit Edison Company, COMBUSTION, November 1934; Part II by C. W. Gordon, The Superheater Company, COMBUSTION, December 1934.

[2] See Edison Electric Institute Publication C4, "Boilers, Economizers, Air Heaters & Piping," 1935.

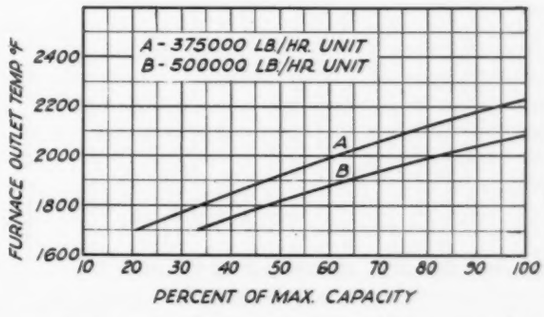


Fig. 7—Typical relationship between furnace outlet gas temperature and rating

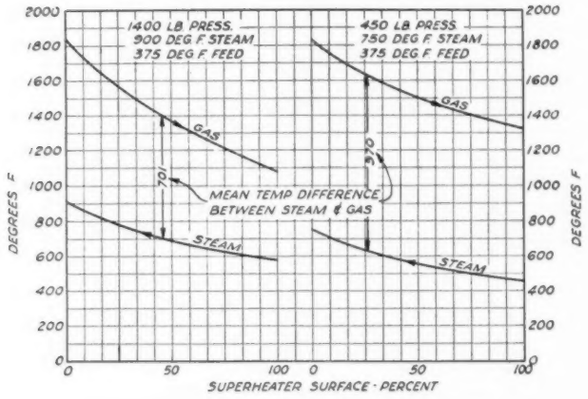


Fig. 8—Comparing mean temperature difference between gas and steam for high and moderate steam temperature units

drums to receive additional tubes, and tube surface is, in itself, comparatively inexpensive. As a means of reducing the temperature of the gases to a point such that the final reduction may be economically accomplished by an air heater, such surface may be more economical than economizer surface. This is particularly true if the feedwater inlet temperature is high. The boiler, in Fig. 2, is an example illustrating this point. In this unit the use of 2-in. tubes in the rear bank assists materially in arriving at the desired results.

In the economizer one degree rise in water temperature corresponds to a fall in gas temperature of approximately 3.25 and 3.07 deg, with final steam temperatures of 900 and 1000 F, respectively. These values are based on 25 per cent excess air and 375 F feedwater inlet temperature. Between 375 F and steaming temperature at boiler pressure lies a range of temperature running from 111 deg at 600-lb pressure to 230 deg at 1600 lb. Raising the feedwater to the steaming point from 375 F, therefore, corresponds to a fall in gas temperature varying between the limits of 364 and 750 deg with 900 F steam and between the limits of 344 and 705 deg with 1000 F steam. With proper precaution in design, steam generation in the economizer is permissible. This, however, will rarely be found necessary or desirable, as a lesser absorption of heat than this almost invariably will be sufficient to bring the gas temperature within the limits, which may be economically accepted by the air heater.

At the maximum rating a final gas outlet temperature from the air heater of less than 350 F is rarely desirable—in many cases not less than 400 F. The manner and extent to which air heater performance varies in response to change in design variables is indicated in Table I. In this table the following constants are assumed: Excess air, 25 per cent; inlet air temperature, 80 F; ratio of specific heat of the products of combustion to the specific heat of air, 25 to 24. No allowance is made for radiation loss or leakage, hence, the values at best are but closely approximate.

It will be noted that by varying the design constants a wide range of "gas in" temperature may be accounted for.

Ninety per cent of the total air through the heater is more than is usually attainable after allowing for dilution of hot air for mill operation to a permissible temperature and for leakage around soot blowers, observation and access doors, ash-discharge doors and miscellaneous points. Eighty-five per cent is probably as high as should be figured at top rating. It will be less at lower ratings since much of the leakage remains constant and none of the allowances recede in proportion to rate of load reduction.

TABLE I

Air through Heater Per Cent	Gas Temp. Heater Outlet Deg F	Temperature Differential between Gas in and Air out, Deg F 200 Gas In	200 Air Out	150 Gas In	150 Air Out	100 Gas In	100 Air Out
80	300	354	154	481	331	610	510
	350	530	330	660	510	788	688
	400	710	510	839	689	968	868
85	300	368	168	529	379	690	590
	350	580	380	741	591	903	803
	400	790	590	950	800	1114	1014
90	300	384	184	591	441	800	700
	350	641	441	850	700	1060	960
	400	900	700	1110	960	1320	1220

Furnace Width

With the trend to higher unit capacity the output of steam per foot of furnace width tends to increase—and for two principal reasons: first, to get within existing space limitations; second, to obtain acceptable furnace

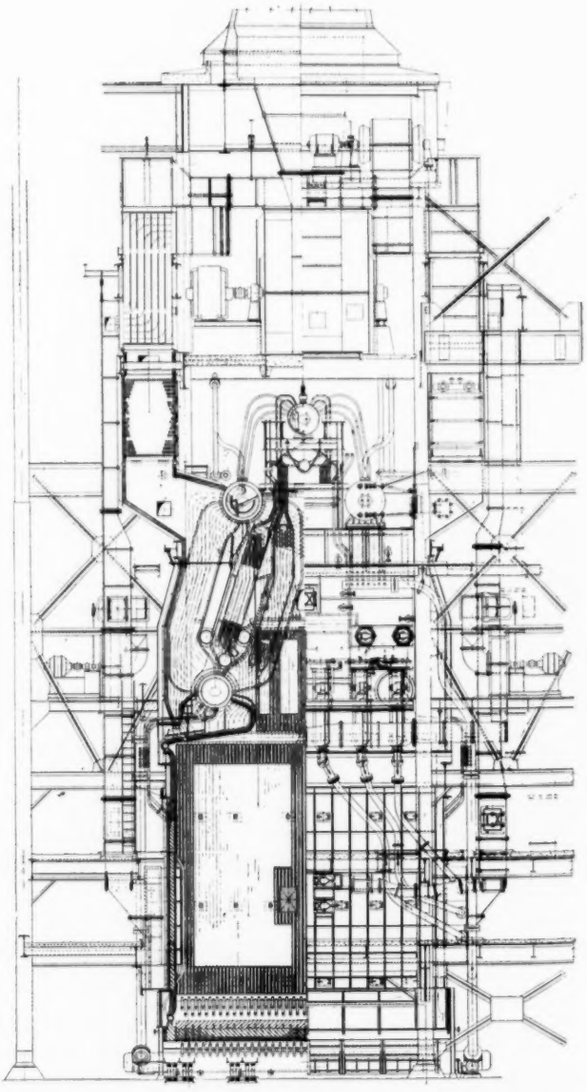


Fig. 9—Cross-section of 900,000 lb per hr, 1400-lb pressure, 900-deg steam temperature unit at Rouge Plant of the Ford Motor Co.

proportions. The Ford Motor Company unit (Fig. 9) for 900,000 lb steam per hr, goes within the same column spacing as the initial units for 250,000 lb per hr. The steam output per foot of furnace width is 35,156 lb per hr. In its essential elements the unit is two boilers facing one another over a common furnace and interconnected through water walls and a steam drum common to both. So arranged a large amount of boiler, superheater, economizer and air heater surface is provided per foot width of furnace without incurring prohibitive draft losses. The Logan, West Virginia unit (Fig. 10) for 1,000,000 lb of steam per hr, is of the same general type. The furnace width is $37\frac{1}{2}$ ft wide and the capacity per foot furnace width is 26,666 lb per hr. To build either of these units as a single boiler element would have meant some radical departure in design to avoid a prohibitive draft loss or alternatively an excessive width and a long, narrow, badly proportioned furnace.

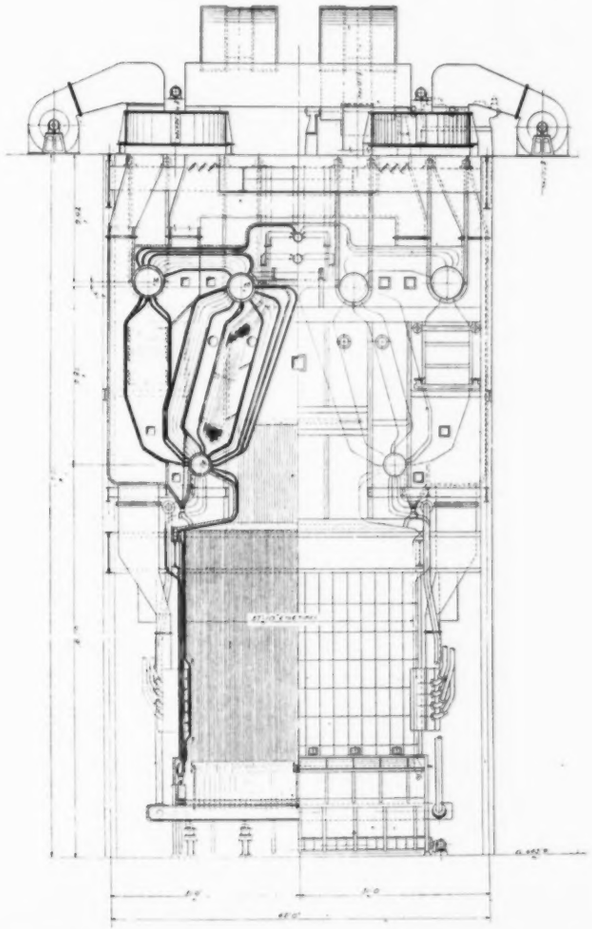


Fig. 10—Approximate cross-section of 1,000,000 lb per hr, 1425-lb pressure, 925 F steam temperature unit on contract for the Logan, W. Va., Station of the Appalachian Electric Power Company

The double or "twin" type of design has little application for other than very large units. At a steam output of 20,000 lb per foot of width, for example, a 500,000 lb per hr unit will have a 25-ft furnace width. These are the figures for the New York Edison boilers and the guaranteed draft loss at full rating up to the air heater outlet is 8.3 in. The plan dimensions of the furnace, namely, 25 ft 1 in. by 23 ft 7 in., are very satisfactory for the tangential system of firing adopted.

Smaller units of around 300,000 lb per hr capacity may be designed with a steam output of 15,000 lb per hr or even less and very satisfactory furnace proportions attained. A considerable number of such units have been so built or are on contract.

What the limit may be of steam output per foot of width and of capacity of a one-sided unit is not established with any degree of precision. As an example of what can be done, both with reference to capacity and to physical dimensions, the Port Washington boiler (Fig. 11) placed in operation last October by the Milwaukee Electric Railway and Light Company, is of interest. This is a one-sided unit designed for 1390-lb pressure and of 690,000 lb per hr capacity, with a furnace width of 55 ft giving a steam output per foot of 12,545 lb per hr. The Logan job for 1,000,000 lb per hr, with no rigid limitations as to space, worked out best as a double unit. As already noted very acceptable furnace proportions and operating characteristics were attained in the units for New York Edison Company for 500,000 lb per hr in a single unit design. From this it would appear that the limit for desirable design of a one-sided unit lies somewhere between 500,000 and 1,000,000 lb of steam per hr.

Steam capacities per foot of furnace width being adopted for current design of large units places stoker equipment of all types at a disadvantage with pulverized fuel. For a single unit 20,000 lb of steam per foot width means 2000 lb of good coal or the equivalent of a stoker

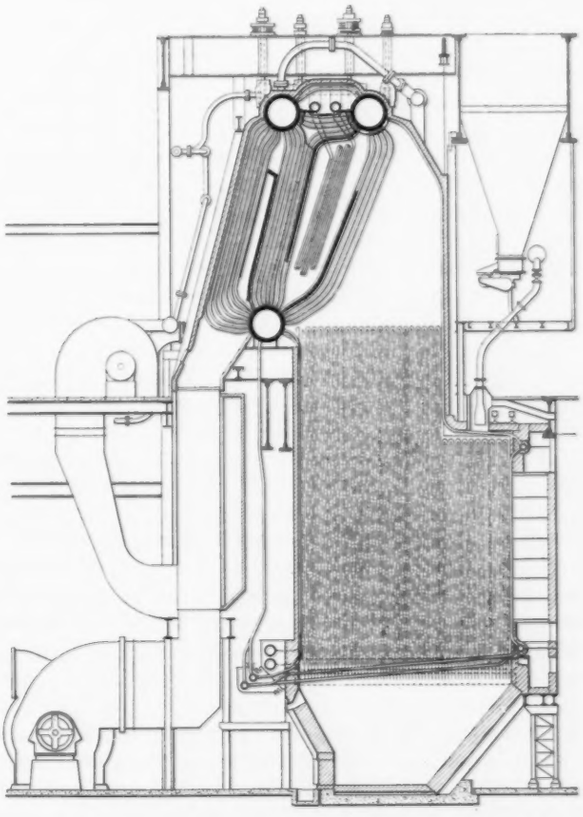


Fig. 11—Cross-section of 690,000 lb per hr, 1390-lb pressure unit at Port Washington Station of the Milwaukee Electric Railway & Light Company

20 ft long operating at a rate of 100 lb per sq ft of grate surface per hour. Is it possible? Is it practical? It sounds difficult. The zenith of stoker capacity per square foot of grate, thus far attained, is in the units at the Hudson Avenue Station of the Brooklyn Edison Company, for a single-ended unit, and more recently in the double units at the Conners Creek Station of the Detroit Edison Company. At both these installations ratings in excess of 80 lb per hr per square foot have been realized.

Steam Washers

Steam washers bid fair to become a standard element of equipment. They have pretty well proved to be the answer, in high-pressure installations, to the difficulty experienced from deposit of solids on the turbine blading. Several designs have been established as satisfactory equipment and others are in process of development. All use the feedwater, low in concentration of solids, as the washing medium. By substituting this water as the moisture normally carried over by the steam for the relatively high concentrated water maintained in the boiler and reducing the amount to a minimum, the solid content is correspondingly reduced to a very low value.

Furnaces

In addition to its function as a combustion chamber the furnace, in the normal installation, absorbs as much heat as the boiler, superheater and economizer combined. It must do so if the essential requirement that the suspended ash particles be cooled to a temperature below their fusion point is fulfilled. In the design of furnaces for these high-temperature units the first point to determine is the minimum furnace outlet temperature required to permit a practical design of superheater. (See Figs. 5 and 6.) This temperature may then be raised, with discretion, to a point approaching the fusion temperature of the ash. For a nice operating job a margin of a hundred or more degrees is desirable. Very frequently, however, the fusion temperature is too low to permit this.

The character of surface forming the furnace wall should be sufficiently effective from a heat absorption point of view to enable the disposition of enough surface around a furnace of reasonable volume to do the required amount of cooling; also consideration should be given to the ability to stabilize furnace operation to a degree such that wide variations in furnace outlet temperature will be avoided. True, the superheater bypass damper, already discussed, may be relied upon to a limited extent to compensate for abnormal variations in furnace outlet temperature. The influence of this damper, however, should be reserved as much as possible to compensate for the inherent variation in superheat temperature over a range of load. It should not be an antidote for bad burner and furnace performance. If the furnace cooling surfaces become fouled with slag and ash accumulations the outlet temperature goes up and a slagging tendency is created or aggravated in the screen ahead of the superheater and even in the superheater tube bank as well; and operating conditions go rapidly from bad to worse.

In the lowermost zone of the furnace accumulations of slag or ash on the walls is limited by the melting action of the high temperature at this point. Since radiant heat transfer is a function of the difference between the temperatures to the fourth power of the radiant body and the receiving surface, respectively, a limited accumulation in this zone is not fatal. The fourth power function eradicates the importance of the lower value. In the upper reaches of the furnace, however, cleanliness of the surfaces becomes increasingly important. It has been found very advantageous in certain instances to adopt a routine of periodic cleaning.

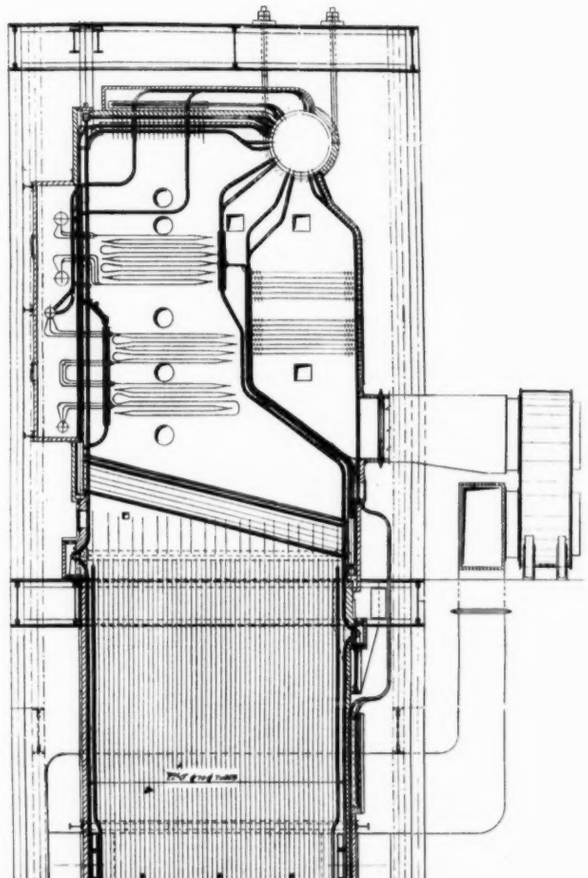


Fig. 12—Approximate cross-section of 300,000-lb per hr 1400 lb pressure 915 F steam temperature unit on contract for the Northeast Station of Kansas City Power & Light Co.

As a further contribution to a stabilized condition every effort should be exerted to eliminate stratification of gases and the consequent variation in temperature across the gas stream, delayed combustion, etc., that go with it. Even distribution of fuel from a mill unit to a multiplicity of burners is difficult but it should be approximated as closely as possible. To the extent that the delivery from the burners intermingle in the furnace, compensation for inequality of fuel supply is secured. In all units referred to, the tangential system of firing from the four corners of the furnace has been adopted. With a muzzle velocity from each corner of the order of 100 ft per sec or more, directed tangentially to the circumference of a circle centered in the furnace, rather complete compensation is secured. In addition, the violent furnace turbulence results in a very rapid combustion and the production of a very high temperature.

Modernizing the Conners Creek Power Plant—VII

Condensers, Feed-Heaters and Their Auxiliaries

By **SABIN CROCKER**

Engineer, The Detroit Edison Company

In the preceding installment it was stated that the May issue would contain the concluding article of the series. However, the space requirements have made it necessary to defer the operating performance and tabulation of equipment until the June issue. The present article deals with rebuilding the old condensers to meet the increased capacity, which was rendered possible by new tube layout, employment of regenerative feedwater heating, chlorination and reduced circulating water per kilowatt due to improved steam consumption of the present units. Provisions for deaeration are described as well as the condenser auxiliaries.

ABILITY to re-use the old condensers has already been mentioned briefly among the reasons why the canal system remains essentially as originally designed.[1] The improved heat cycle and steam conditions of the new units, together with the modernized arrangement of condenser tubes, made possible re-using the old condenser shells and circulators for the installation of larger turbine-generators. Many of the attendant auxiliaries were likewise incorporated in the rebuilt plant.

The old Conners Creek plant contained three sizes of condensers which could be re-designed for the two sizes of new units. Through careful study of the various items involved, it was found that: (1) the old 20,000-kw condensers could be used for the new 30,000-kw units; and (2), with certain additions and modifications, the old 30,000-kw condensers of Delray and Conners Creek, as well as those of 45,000-kw size, could be re-used for new units up to 60,000-kw capacity.

The increase in boiler-drum pressure from 245 to 710 lb required that serious consideration be given to deaerating feedwater. The occasion of retubing the condensers offered an opportunity to install in each a simple make-up water spray system capable of reducing the oxygen content of the feedwater to 0.01 ppm or less. Each of these phases of condenser- and feedwater-equipment rehabilitation will be taken up in turn.

Condensers Have New Tube Layout

The old plant, as already described, operated on a Rankine cycle with feedwater heating by exhaust steam from the auxiliaries.[2] The new units operate on a regenerative feed-heating cycle. One of the advantages of this change is that a sizeable portion of steam condensation is transferred to the feedwater heaters, thus making possible use of the old condensers with appreciably larger turbines.

The tube layouts of the old condensers were rearranged so as to reduce substantially the back pressure and undercooling losses. This was accomplished even in the case of the old 30,000-kw condensers re-used for 60,000 kw units, despite an increase with the larger turbines of about 20 per cent in the weight of steam to be condensed. At the same time, and as an offset against the decrease in tube surface, the rate of heat transfer was increased by using a higher water velocity within the tubes. The ensuing increase in water-friction factor was partially modified by using bell-mouth ferrules to decrease entrance loss. Despite higher water velocity, the reduced number of tubes remaining in the revamped condenser require a smaller total quantity of circulating water than was used originally. The increased condensing capacity is thus obtained at a slight saving in pumping power, since the increase in friction-head power is more than offset by the decreased power for pumping a smaller quantity of water.

With the exception of the two old 30,000-kw size, the condensers were not moved from their original positions. Table XII indicates the various phases in the rehabilitation on the old condensers, and gives the approximate amount of surface that will be used in the proposed re-arrangement. Since the old 20,000-kw condensers are of earlier design, the changes required in old Nos. 1, 2, and 3 will be discussed first, followed by a discussion of the re-design of the other two larger sizes for use with the 60,000-kw units.

In adapting the 20,000-kw condensers to the new 30,000-kw units, the total condensing surface remains approximately the same. A comparison of design data for the old 20's and new 30's is shown on Table XIII. About 16 per cent of the surface, however, is now in the four feedwater heaters which condense approximately 28 per cent of the throttle steam flow. The reduction of surface through re-arrangement of tubes in these two-pass condensers in which the tube bundles were concentric with the shells, was necessary in order to provide adequate steam lanes down to the hotwell and lower

[1] COMBUSTION, November 1935.
[2] COMBUSTION, February 1936.

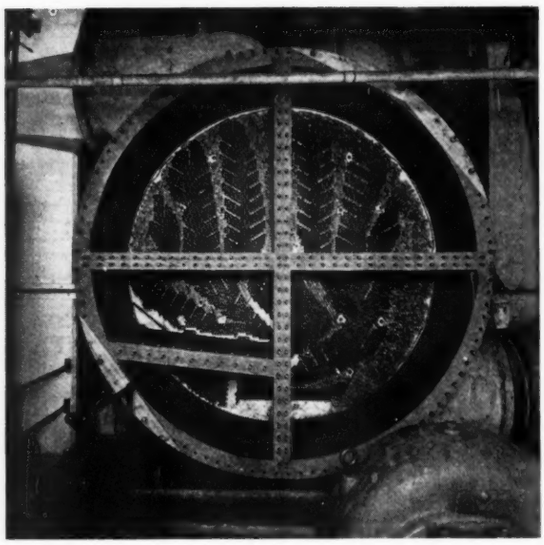


Fig. 58—Improved tube layout for old 20,000-kw condenser adapted to new 30,000-kw Unit 8

tubes sections as shown in Fig. 58. The latter probably had effected little or no condensation in the past, and certainly had caused considerable uneconomical under-

TABLE XII
CHANGES IN COOLING SURFACE MADE IN REHABILITATED CONDENSERS

	Nos. 1, 2 & 3 Conners Creek	No. 4 Conners Creek	No. 6 Conners Creek	No. 10 Delray	No. 8 Conners Creek
Old condenser designation					
New condenser numbers at Conners Creek	8, 9, 10	11	12	13	14
Maximum capacity of tube sheet, sq ft	35,000	82,000	80,600	42,700	44,000
Surface installed in original design, sq ft	32,500	60,618	65,627	38,430	39,550
sq ft/kw	1.625	1.347	1.458	1.281	1.318
Design changes in 1930 sq ft		50,300	52,046		
sq ft/kw		1.118	1.157		
Final design sq ft (including external air coolers for Units 13 & 14 only)	27,000	40,000*	40,000*	37,300	37,300
sq ft/kw	0.900	0.667	0.667	0.622	0.622

* Approximate surface, subject to revision until unit enters service.

cooling. This re-arrangement of the tube-sheet layout involved taking out some thousand tubes together with all baffles in the steam space outside the air cooler.

TABLE XIII
DESIGN DATA FOR MAXIMUM THROTTLE FLOW OLD 20's VS NEW 30's

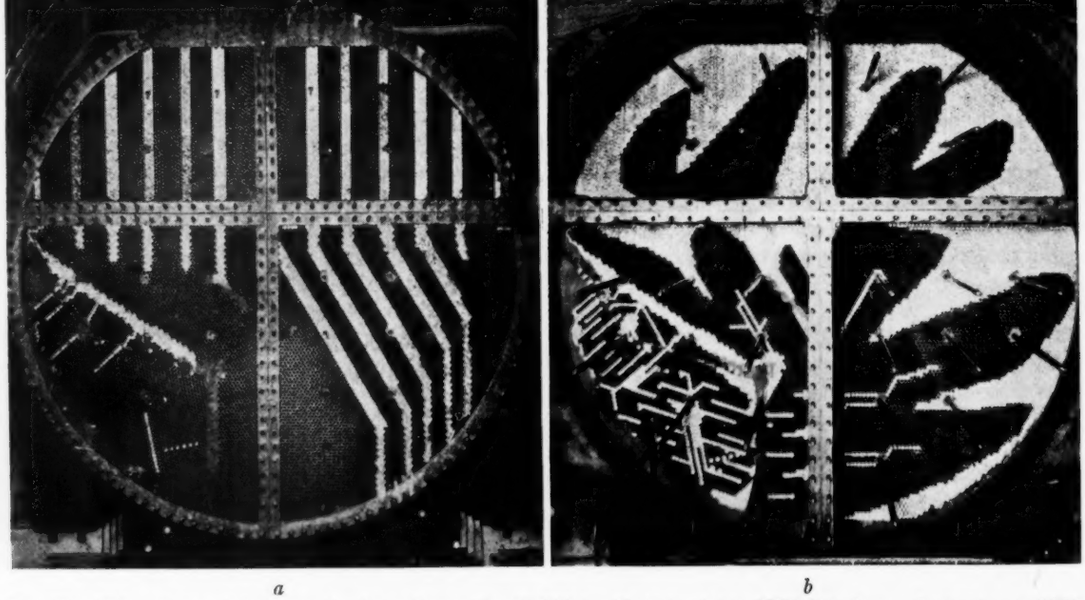
Item	Old Twenties 1, 2, 3 Condenser	New Thirties 8, 9, 10 Condenser	Feedwater Heaters, Stages 14	11	8	4
Back Pressure, lb per sq in. abs (or in. hg)	1 in.*	1 in.	8.8	36	94	209
Steam temperature, F	79	79	187.5	297	459	618
Superheat, F				36	136	233
Water temperature leaving, F	74	79	182.5	259	323	388
Steam flow as % of throttle flow	100	71.7	6.2	7.6	6.8	7.7
New cond flow as % of old cond flow		89.3				
Condensing surface, sq ft	31,820	27,000	1025	1363	1340	1340
Sq ft of surface per kw	1.591			1.089		

* Nominal back pressure corresponding to a circulating water temperature of 50 to 60 F.

Salvaging both the 30,000- and 45,000-kw condensers for use with new turbines up to 60,000-kw capacity had an important bearing upon the final decisions of the rebuilding project. The two smaller condensers for Units 13 and 14 were obtained from the two old Delray and Conners Creek 30,000-kw units, the generators of which were used with the new high-pressure high-temperature turbines Nos. 8 and 9.[3] The two old 45's, Nos. 4 and 6, will be used in their present positions for new Units 11 and 12. Some idea of the expected performance of the new units can be obtained from Table XIV, which indicates among other things that the feedwater heaters with 20 per cent of the total surface should condense about 26 per cent of the throttle steam flow. The condenser and feedwater heaters will contain an aggregate surface of about 0.8 sq ft per kw.

Modernization of the 30,000-kw condensers, because they are of the bell or eccentric type, did not require the provision of a special steam lane to the hotwell as in the small condensers previously described. Some 4500 sq ft of tube surface, however, were taken out of old No. 8 condenser in re-arranging the tube layout for use with new Unit 14 to utilize more effectively the lower sections of the condenser and to reduce steam- and air-friction pressure loss. About 2100 sq ft of this withdrawn surface was replaced by an external air cooler, see Fig. 62,

[3] COMBUSTION, November 1935.



a *b*

Fig. 59—Old and new tube layouts of condenser for 45,000-kw Unit 4. (a) in 1917, (b) after redesigning in 1930

Fig. 60—General view of chlorination house

resulting in a considerably more economical design than if that same surface had remained within the condenser shell. To accommodate the new external air cooler, the atmospheric relief connection was changed from the side to the end of the condenser. The main baffle of the internal air cooler was shortened and all other baffles within the condenser shell were taken out. Part of what constitutes the air cooler is, therefore, inside the shell and part outside.

Revamping the 45,000-kw condensers follows about the same process. External air coolers, however, are not necessary for converting this larger-sized condenser to use with the 60's. Fig. 59 (*a*) shows the original tube-sheet layout for condenser No. 4 when it was installed in 1917. Fig. 59 (*b*) is the tube-sheet of the same condenser after being re-designed in 1930 to reduce the exhaust losses and back pressure of the 45,000-kw unit. No. 6 condenser tube-sheet, also re-arranged at about the same time, is slightly different in minor respects. Performance and test data on the 1930 design indicate that even more tubes can be taken out to effect still better operation with the new 60,000-kw turbines.

Chlorination of Circulating Water

Operating experience with chlorinating equipment installed at Conners Creek several years in advance of the present rebuilding project demonstrated that the addition of chlorine solution to river water used for general service and condenser cooling materially reduces the adherence of slime to tubes and water boxes. Experiments with chlorination were started at Conners Creek in June 1930, when simple temporary equipment was installed for old No. 3 condenser only. After a beneficial result in the form of cleaner tubes was apparent, the Company felt justified in going ahead with the construction of a separate chlorinating house situated over the inclosed section of the south intake canal, and the No. 3 condenser temporary installation was dismantled.

In connection with rehabilitating the north canal to supply Units 13 and 14 at the north end of the plant, a new trash rack will be built across the main intake canal and, in place of the present wooden building, a permanent structure will be provided to house the existing chlorinating outfit plus supplementary equipment of more modern design.

The present chlorination building shown in Fig. 60 houses all the essential equipment except the large lime-

TABLE XIV

DESIGN DATA FOR MAXIMUM THROTTLE FLOW OLD 30'S AND 45'S VS NEW 60'S

	Old Units		New 60,000-kw Units					
					Feedwater Heaters—Stages			
Item	Nos. 8 & 10* 30,000 kw Nos. 4 & 6 45,000 kw	Condenser	Unit No.	Condenser	11	Evaporator Condenser	Evaporator	8	4
Back pressure, lb per sq in. abs (or in. hg)		1 in.**		1 in.	8.7	15.3	47.5	47.5	165
Steam temperature, F		79		79	187	214	378	378	562
Superheat, F							100	100	196
Water temperature leaving, F					182	209	214	276	368
Steam flow as % of throttle flow		100		73.4	7.6	1.6	1.9	6.5	10.6
New cond flow as % of old cond flow	4, 6			85.0					
	10, 8			122.4					
Condensing surface, sq ft***	4	50,300	11	40,000	2100	1655	194	2630	2690
	6	52,046	12	40,000	2100	1655	194	2630	2690
	10	38,430	13	37,300	2100	1655	194	2630	2690
	8	39,555	14	37,300	2100	1655	194	2630	2690
Condensing surface, sq ft per kw	4	1.118	11	0.821					
	6	1.157	12	0.821					
	10	1.281	13	0.776					
	8	1.319	14	0.776					

* Old Units 8 and 10 from which 30,000-kw generators were removed to use with new Units 8 and 9.
** Nominal back pressure corresponding to a circulating water temperature of 50 to 60 F.
*** Condensing surface subject to change.

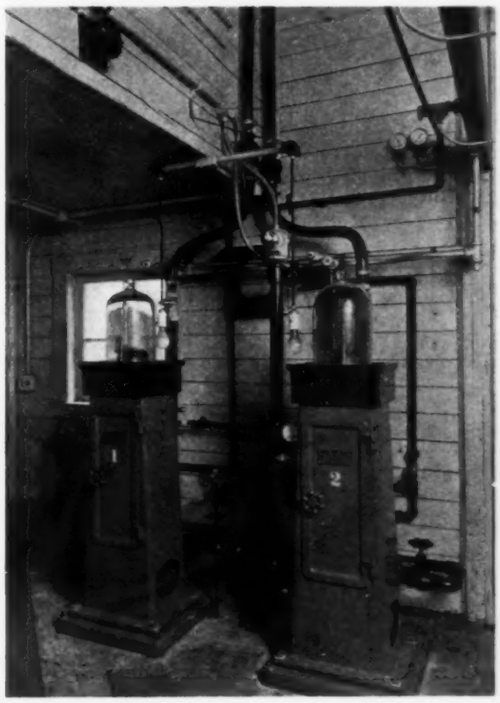


Fig. 61—Metering equipment inside chlorination house

stone fixing tank situated out-of-doors. Liquid chlorine is stored in three 2000-lb tanks at 70–110-lb pressure. Gas is drawn off at a pressure reduced about 15 lb by a throttling valve and piped to the operating equipment shown in Fig. 61, where the pressure is further reduced. This equipment, which is mounted inside an inverted glass bell-jar resting in a water tray, operates under vacuum. The essential apparatus inside the jar includes a float-operated needle-valve for the additional gas-pressure throttling, and an interchangeable metering device to measure up to 300 lb per day of chlorine gas. In the meter a predetermined amount of chlorine gas is dissolved in a small amount of water under slight vacuum produced by a water-operated ejector, the discharge of which also serves to dilute the rich chlorine solution coming from the meter by mixing it with about four times as much more water. The greater quantity of water is necessary to completely dissolve the gas and reduce the proportion of free chlorine. General-service water after passing through a fairly fine-mesh screen to minimize the entrained matter, is used for both the metering equipment and the mixing ejector.

To prevent evolution of free gas and at the same time to afford storage, there is provided an impregnated-cypress-wood tower filled with limestone which has a net storage of 1000 to 4000 gal depending on the condition of the limestone. The chlorine water leaving the ejector is piped continuously to the tower, from which, in turn, it is intermittently discharged to the intake canal as required by operating conditions in the power-plant condensers.

The chlorine dosage given the circulating water depends upon river-water temperature, the season, the plant load and other factors. Under average conditions the dosage required to maintain from 0.3 to 0.5 ppm residual in the condenser circulating-water discharge varies from 0.4 ppm of chlorine in winter to 1.0 ppm in summer. The discharge from the limestone tower, automatically controlled by an adjustable mercoid-switch clock, varies from approximately 6 min every $1^1/_2$ hr in the winter to roughly 5 min every 20 min in the summer. Such a schedule applies only to Conners Creek; widely variant water characteristics as found down-river at Delray or Trenton Channel require different dosages appropriate to local conditions.

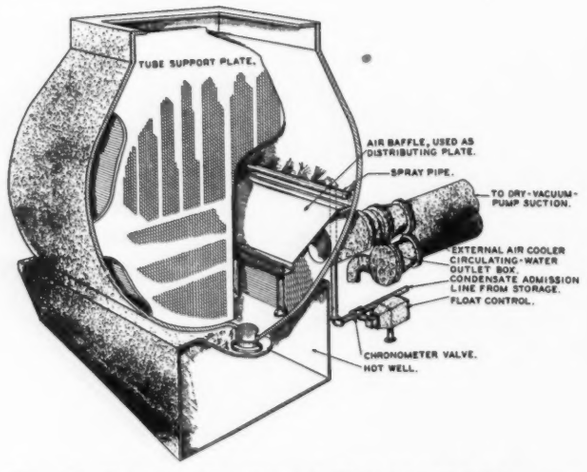


Fig. 62—Cross-section through Unit 14—60,000-kw condenser at first tube-support plate, showing condensate make-up deaerating spray

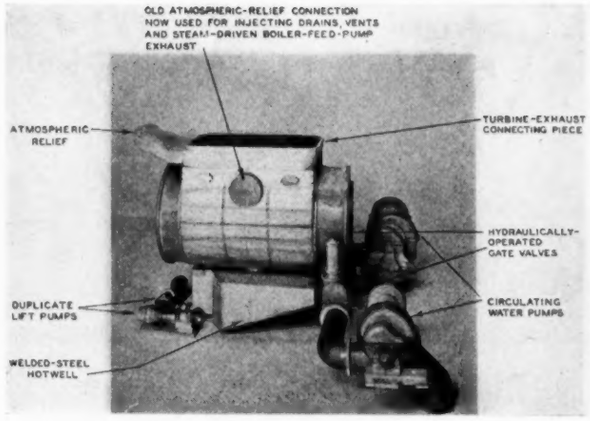

OLD ATMOSPHERIC-RELIEF CONNECTION NOW USED FOR INJECTING DRAINS, VENTS AND STEAM-DRIVEN BOILER-FEED-PUMP EXHAUST
ATMOSPHERIC RELIEF
TURBINE-EXHAUST CONNECTING PIECE
HYDRAULICALLY-OPERATED GATE VALVES
DUPLICATE LIFT PUMPS
CIRCULATING WATER PUMPS
WELDED-STEEL HOTWELL

Fig. 63—Model of condenser for Unit 14

Chlorination has proved satisfactory. Since it was applied to the whole plant in May 1931, no condenser has required plug cleaning. As the equipment was in good condition when the rebuilding program got under way, it was continued in service without alteration. Reduced back pressure as a result of cleaner condensers influenced to some extent the ability to adapt the old condensers to larger turbines.

Reduced Circulating-Water Consumption Saves Canals

Substantial reductions in the maximum amount of circulating water required per kilowatt of installed capacity have been effected through regenerative feed-water heating, improved condenser design and chlorination. This suggested the possibility of still being able to use the existing canal system without extensive changes, even for a rebuilt plant of nearly double the original size. The switch to regenerative feed heating coupled with the increase in steam pressure and temperature accounted for a reduction of about 37 per cent in the pounds of steam per kilowatt-hour going to the condensers, with a corresponding decrease in the amount of circulating water required. A further reduction in the demand for circulating water was effected through altering the tube layout of the condensers and installing chlorinating equipment.

The old canal system, before this conservation of circulating water had been made, was counted on for supplying an aggregate maximum demand of 430,000 gpm, corresponding to nearly $2^1/_2$ gpm per kw of capacity in the old plant. As a result of the improvements in plant cycle and equipment design, it has been possible to reduce the maximum quantity of circulating water required per kilowatt to $1^1/_3$ gpm, which corresponds to an aggregate maximum demand of only 440,000 gpm for a 330,000-kw plant.

During the early stages of rebuilding Conners Creek, hydraulic tests were made on a suitable scalar model to determine the adequacy of the existing canal system for supplying the enlarged plant, taking into account the concentration of new large units at the north end remote from the river. Tests on the model showed that by breaking a single bulkhead to join the previously independent north and south intake canals, and by augmenting a portion of the overflow canal with a parallel passageway previously used for cables until Essex Station was placed in commission, the existing canal system can be made altogether adequate. Rebuilding and enlarging the

plant up to 330,000 kw is proceeding, therefore, with only minor changes in the canal system.

Condenser Spray System Deaerates Make-up Water

Improved deaeration equipment was designed and installed by the Company at the time this re-arrangement of condenser tubes was in progress. Since, with boiler pressure of 400 lb and upward, corrosion becomes a factor of major importance, it is essential to reduce the oxygen content to a negligible quantity when using an untreated or slightly treated boiler water. As a simple and inexpensive means of deaerating condensate and distilled make-up, attention within the Company has been directed toward deaerating oxygen-bearing water by flashing it into the main-unit condenser or low-pressure bleeder heater. Oxygen enters the feedwater system at points where condensate is in contact with air such as shaft seals and storage tanks, also through equipment under vacuum and thus subject to air infiltration as in the building-heating-returns system, water-sealed valves, etc.

To accomplish deaeration, makeup water is introduced into the main-unit condensers through a header extending the length of the steam space which is equipped at definite intervals with spray nozzles pointing toward the condenser shell. For the most effective deaeration to take place, adequate pressure differential must be provided to insure good dispersion of the make-up water ejected from the spray nozzles. From the inside of the shell, the make-up drips either on to the main baffle of the air cooler or on to the inside of the condenser shell, as the case may be in different condensers, down which it flows in a thin sheet, see Fig. 62. Where possible the main air baffle is used in preference so that the liberation of air takes place closer to the air cooler and hence at a lower absolute pressure. As oxygen content of the amount present in this case has little corrosive effect on cast iron no special precaution is required in the case of the Conners Creek condenser shells.

The Company's designers feel that the thinner the layer of water on the shell or air baffle, the better is the secondary or final deaeration as surface friction will cause desirable turbulence to expose new water surface and free the entrained air. Advantage is taken of the fact that entrained air is withdrawn more easily when the make-up enters at elevated temperatures by providing for recirculation of storage water at times through the auxiliary-dc-unit air-ejector condensers, by which means the water temperature may be raised to about 110 F.

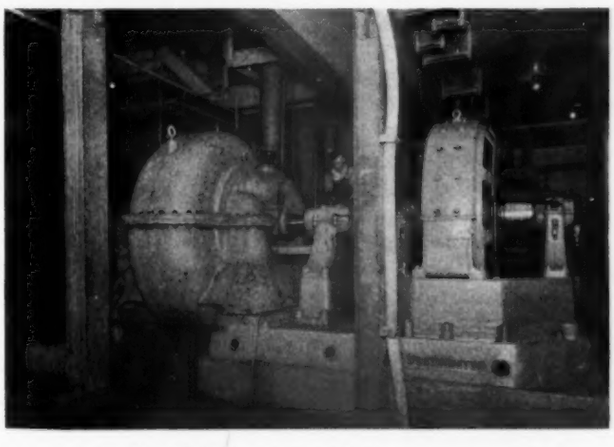


Fig. 64—60,000-gpm circulating-water pump

Fig. 65—30-cfm reciprocating dry-vacuum pump

Oxygen content of the feedwater is determined by a modified Winkler method using a root starch. This method was developed by Subcommittee 8 of the Joint Research Committee on Boiler Feedwater Studies and published in the 8th Edition of the American Public Health Association publication, "The Examination of Water and Sewage." Tests indicate that the oxygen content is held below 0.01 ppm at the feedwater discharge of the high-pressure heaters.

Welded-Steel Hotwells Installed

The installation of greater hotwell capacity as a part of the condenser rehabilitation program was dictated by the need for providing a water-storage reservoir between the condenser and lift pump. The varying level of this storage water, such as occurs at times of load change, provides a means of actuating the float-controlled chronometer valves which admit or discharge condensate as the hotwell level falls or rises. The operation and function of these chronometer valves are discussed in full under the heading "Details of New Plant Cycle."[4] Experience at the Trenton Channel plant indicated that to avoid cavitation with hotwell and boiler-feed pumps driven at high speed, a lift pump must be provided to boost the inlet water pressure of the hotwell pump. To avoid cavitation within the lift pump it, in turn, must be depressed to an elevation where the eye of the impeller is at least two to three feet below hotwell level, and the pump run preferably at a comparatively slow speed. Since the hotwells of the old units were unsuited for the new requirements, they were replaced by larger ones of welded-steel construction as shown in Fig. 63 which was photographed from a model of the condenser for Unit 14.

Reasons for using welded steel rather than cast iron in making new hotwells for the old cast-iron shells are as follows: (1) The relatively large storage capacity, to be hung with a special load distribution from the condenser and inside the small space available between the foundations, required the use of a peculiar shape. (2) This shape, which would have been difficult to cast, lent itself readily to welded-steel fabrication on the site. (3) With barely a trace of oxygen in the condensate, corrosion of steel would be slight. (4) The placing of

[4] COMBUSTION, February 1936.

TABLE XV

RE-ALLOCATION OF OLD CIRCULATING-WATER PUMPS

Conners Creek New Unit		Served by Pumps					From Old Units		
No.	Kw	Location	Maximum gpm	Approx Head in ft	dc Motor Drive Speed rpm	dc Motor Drive Horsepower	No.	Plant	Kw
8	30,000		36,000	16	280–375	200–250	1	CC	20,000
9	30,000		36,000	16	280–375	200–250	2	CC	20,000
10	30,000		36,000	16	280–375	200–250	3	CC	20,000
11	60,000	N	60,000	19.5	150–300	225–450	4	CC	45,000
		S	30,000	23	350–440	300	10	D2	30,000
12	60,000	N	60,000	19.5	150–300	225–450	6	CC	45,000
		S	30,000	23	400–450	300	8	CC	30,000
13	60,000	N	30,000	23	400–450	300	8	CC	30,000
		S	60,000	19.5	150–300	225–450	4	CC	45,000
14	60,000	N	30,000	23	350–440	300	10	D2	30,000
		S	60,000	19.5	150–300	225–450	6	CC	45,000

CC = Conners Creek Plant D2 = Delray Power House 2

a large casting would require the removal of a part of the existing condenser-room floor, not necessary for the placing of steel plates welded together in their final position. (5) Welded steel added a minimum amount of extra dead weight. Lastly (6), the Company's engineers were able to introduce economies of construction, and to maintain complete control and inspection of each operation.

The new hotwells for the 30,000-kw units provide an active capacity between the full-open high-water float level and the full-open low-water float level of 11,900 lb and a storage capacity below the low-float level of 24,600 lb. The active and storage capacities for the 60,000-kw units are 23,700 and 41,000 lb, respectively. The active capacity represents about $2^1/_3$ min operation of the boiler-feed pump at maximum flow; the storage capacity would last proportionally longer.

Condenser Auxiliaries Re-used

Many of the existing auxiliaries in the old plant were either continued in use without alteration or revamped and put back into service when the new plant commenced operation. A partial list of this equipment includes general-service-water pumps, miscellaneous pumps around the building, air compressors and condenser auxiliaries. These latter will be described briefly here; the others have been already described in the previous sections of this article or were described in the 1915 paper by C. F. Hirshfeld.[5]

All the original circulating-water pumps of the old Conners Creek units and of old Delray No. 10 unit will be re-used. In the case of the new 30,000-kw units, the pumps are left on their present foundations, but for the 60,000-kw units, it was found to be advantageous to coordinate one pump from the old 30's with one pump from the old 45's. These changes can be consummated as required without affecting the operation of the present 45's which may have to be run, but only occasionally, to supply the local area load. Table XV shows the approximate rating of these pumps and the way in which they will be re-allocated to the new units. A photograph of a 60,000-gpm circulating-water pump, the larger size of the two to be used for the new 60's, is shown in Fig. 64. While no changes are contemplated at present, it would be possible to make operation of these pumps somewhat more economical by installing new impellers and rebuilding the dc-motor-speed controllers.

[5] The Conners Creek Plant of The Detroit Edison Company by C. F. Hirshfeld, *Transactions* A.S.M.E., Vol. 37, 1915, p. 1085.

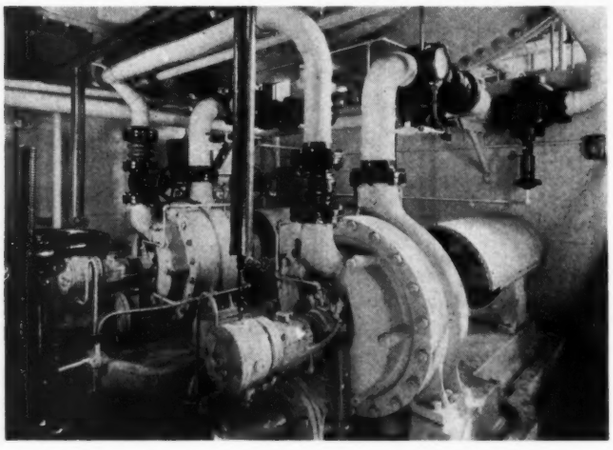


Fig. 66—Revamped lift pumps for new Unit 8

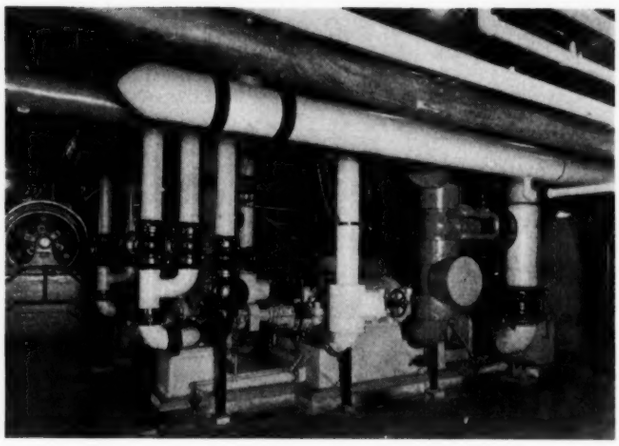


Fig. 67—Duplicate steam- and motor-driven feedwater pumps

The five existing horizontal reciprocating dry-vacuum pumps will be left intact in their old positions for Units 8 to 12, inclusive. Old No. 8 RDV pump will be moved from the auxiliary bay for use with the new main Unit 13. There are two sizes of single-cylinder, two-stage pumps; the 25-cfm size is to be used with the 30,000-kw units, and the 30-cfm size shown in Fig. 65 for the 60,000-kw units. The smaller RDV pumps are driven by 12–40-hp dc motors at 30–100 rpm and the larger by 25–50-hp dc motors at 50–100 rpm. Fifty to sixty revolutions per minute has been the usual speed in past operation.

A three-element, three-stage, steam-operated air ejector is installed with Unit 14 as limited space prevents the re-use of a salvaged RDV pump. The assembly is mounted on an integral, three-stage, cast-iron-shell cooler through which condensate from Unit 14 circulates. Each element is designed to evacuate 0.55 lb per min of free air saturated at $7^1/_2$ F below the temperature corresponding to the absolute pressure at the suction, with a steam consumption of 285 lb per hr at 200–250-lb gage. The temperature of the condensate increases 0.5 to 12 F according to the turbine load and number of elements in use. A 6-in. evacuator, discharging to atmosphere, is mounted on the ejector-condenser shell to reduce the main condenser pressure from barometric pressure to 12-in. mercury in 15 min prior to admitting steam through the turbine throttle.

Lift pumps, which supply a positive pressure at the suction of the hotwell pumps as already outlined, have been adapted from the old hotwell pumps through the use of new impellers. For example, the 6-in. two-

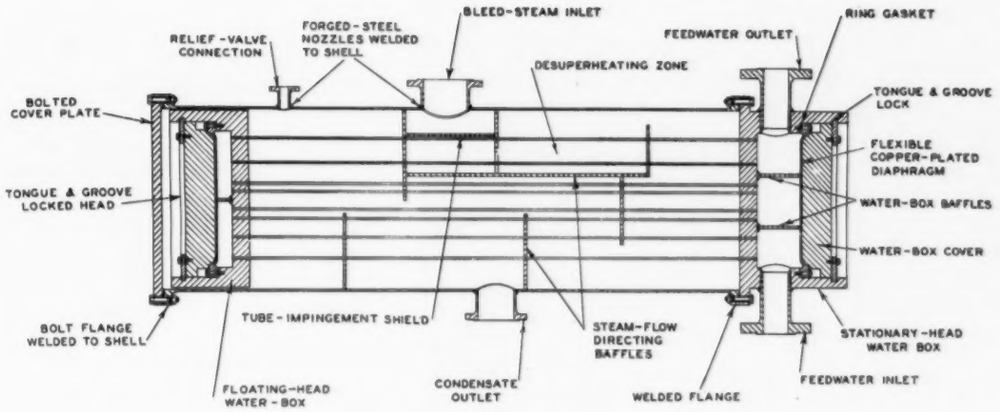
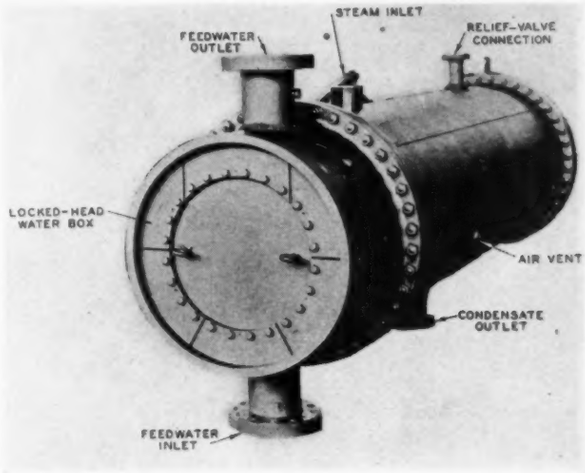


Fig. 68—Four-pass high-pressure feedwater heaters, locked-head design (a) cross-sectional elevation (b) external view showing locked head

stage pump of old Unit 1, which was capable of pumping 500 gpm at 1 in. abs suction against 140-ft head, was reassembled under Unit 8, see Fig. 66, and, with the new impeller, is pumping 600 gpm at 1 in. abs suction against a 150-ft head of water. The old constant-speed 1200-rpm 35-hp dc motor and controller were used without alteration. It is possible to re-use all the old hotwell pumps in the same way even for the 60,000-kw units. The motor controllers will eventually be revamped to permit speed control.

As mentioned in the February installment under "Feed Pumps and Drives" new hotwell and boiler-feed pumps were necessary for the new units to match the higher steam pressure and the introduction of bled-steam feedwater heaters. Table XVI affords a detailed comparison between the old pumps, which were taken out and scrapped, and the new pumps. The steam and motor-driven pumps shown in Fig. 67 are duplicate equipment erected side-by-side in the condenser room. The old boiler-feed pumps were situated in the alcove under the over-hanging mezzanine floor along the inside wall of the turbine room now occupied by the dc house-service units.

Several lesser items are of interest in completing this account of the main condensers and their auxiliaries. The feedwater system has been completely revamped for the higher temperature and pressure. The old barometric feedwater-heating condensers, the hot-boiler-feed and cold-storage riveted tanks along the boiler-room side of the middle wall are all to be taken out as the low-pressure equipment is replaced. To provide cold-water storage for the rebuilt plant, welded steel tanks are being erected as needed in the space between the boiler-room floor and the ground level between the two ash



aisles. The tanks are lined with a corrosion-resisting coating to minimize the action of the oxygen-bearing water. An interesting and economical salvaging operation is evidenced by the trisecting of the old barometric-condenser flooding (or head) tank so as to use one-third for a sealing-water head tank for Units 8, 9 and 10, one-third for sealing-water for the new 60,000-kw Units 13 and 14 and the remaining third intact until old Units 4 and 6 are replaced, when it also will be used for sealing water. In this manner, the old condensers with their usable auxiliaries were incorporated in a modernized plant at a substantial saving in new investment. At the same time, the Company feels that the replacement of the obsolete equipment by more reliable and efficient machinery has both strengthened their ability to maintain continuity of service and reduced operating costs.

TABLE XVI

COMPARISON OF DESIGN DATA, HOTWELL AND BOILER-FEED PUMPS, OLD AND NEW UNITS

		Rating					Electric Drive				Steam Drive			
Pump	Unit	Size of Suction & Discharge	Stages	gpm	Head ft	At rpm	Volts	Current	Speed rpm	Horsepower	Pressure lb	Temp F	Speed rpm	Horsepower
Old Hotwell*	20's	6	2	500	140	1200	235	dc	1200	35				
	30's	6	2	1000	100	1130	230	dc	1150	50				
	45's	6	2	1200	100	1200	235	dc	1200	80				
New Hotwell	30's	5/4	2	608	285	1780	Coupled to Boiler-feed Pump							
	60's	8/6	2	1232	376	1770								
Old Boiler-feed	20's	6	4	1200	770	2000					210	650	2000	325
	30's	6	4	1200	770	2000								
	45's	8	5	1500	740	1170	240	dc	1000/1200	250/450				
New Boiler-feed	30's	6	7	660	1910	1780	4800	ac	1420/1780	90/550	600	825	1780	550
	60's	6	7	1320	1938	1770	4800	ac	1370/1785	350/1100	600	825	1770	994

* These pumps are retained as lift pumps on the new units.

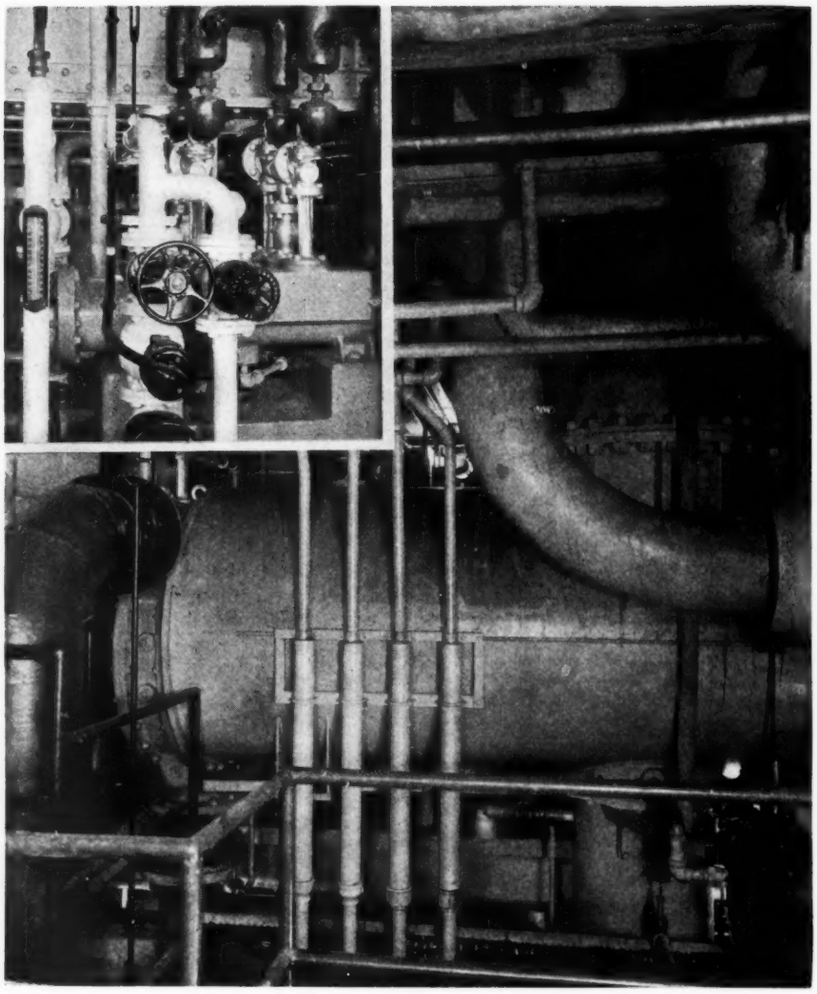


Fig. 69—Auxiliary dc house-service unit condenser No. 1 (inset) steam air ejector for No. 1 dc unit

Feedwater Heaters Have Special Features

Some description of design details for the feedwater heaters is required to supplement the account of their operating conditions under the heading "Regenerative Turbine Cycle" in the February article. Particular significance is attached to the use of a desuperheating zone and the locked-head water-box construction, both of which are shown in Fig. 68.

Steam bled from the 4th and 8th stages of the 30's and the 4th stage of the 60's is quite highly superheated in comparison with past practice at the Delray or Trenton Channel plants. Advantage was taken of this superheat to reduce the terminal temperature difference in the feedwater heaters by incorporating a desuperheating zone around part of the final water pass. Since this zone acts primarily as a gas cooler through which superheated steam flows before reaching its saturation temperature, there is no condensation present in the zone, and hence no tendency to lower the final temperature difference through wetting the tubes. This favorable condition permits designing with a view to raising the feedwater up to, or even slightly above, saturation temperature. The extent to which the bled steam is still superheated when entering the feedwater heaters is shown in Tables XIII and XIV. Approximately 15 per cent of the total heater surface is located within the desuperheating zone of the Conners Creek heaters. The proportion will necessarily change for other installations under different operating conditions. Tubes 10 ft long for the 30's, and 20 ft long for the 60's, were salvaged from old condenser tubes by re-drawing, annealing and cutting to length at a tube mill.

Both high- and low-pressure heaters have shells fabricated of fusion-welded steel plate with forged-steel nozzles attached by welding; water boxes are bolted to flanges welded to the shells. The conventional flange-and-bolt type water boxes used on the low-pressure heaters are designed for 200-lb water pressure. The high-pressure heaters, designed for 1000-lb water pressure, have several new features. The locked-head water boxes, shown in Fig. 68, are fabricated from one-piece upset forgings so as to reduce the number of high-pressure joints. A narrow shoulder is formed by counter-boring the inside of the forging to about half the depth from the open end. With a narrow ring gasket in place, a flexible $^3/_{16}$-in. copper-plated diaphragm with thick flanges is bolted against the shoulder. This dish-shaped diaphragm assembly serves to seal the water box since its heavy rim flanges are not distorted by the flexing of the diaphragm which occurs when the water-pressure load is transferred to the heavy water-box cover. The water-box cover is a substantial circular plate which fits inside the water box, butting snugly against the diaphragm. A groove about $^3/_4$-in. deep is machined inside the water box in line with the outside of the cover plate. Shear pieces about 1 in. thick, which transfer the water-pressure load on the cover plate to the sides of the water box, slip into the groove and are held in place by studs in the cover plate. Easy and inexpensive erection or dismantling and low bolting loads characterize the tongue-and-groove construction.

TABLE XVII

DESIGN DATA OF HOUSE-SERVICE CONDENSERS AND AUXILIARIES

Equipment		dc Unit 1	dc Units 2, 7, 8, 9*
Turbine-generator capacity	kw	2000	2880
Condenser surface	sq ft	2220	3470
Number of tubes		808	1270
Outside diam, gage		$^3/_4$–18	$^3/_4$–18
Exposed length	ft	14.00	13.98
Circulating pump	gpm	2320	4280
	ft	21.0	33.38
	rpm	773	695
Hotwell pump	gpm	65	65
	ft	135	135
	rpm	1940	1940
Steam air ejector—no. of elements		2	2
Free air per element at 1 in. hg	cfm**	1.27	2
Steam consumption	lb/hr	75	120
Steam pressure	psi	175–250	175–250

* Units 3 and 4 are old dc 2000-kw motor generators.
Units 5 and 6 are old dc 1000-kw motor generators.
The continued use of these units will be dependent on subsequent steps of the rebuilding project.
** Referred to 70 F, and 30 in. hg.

The interior of the 14th-stage heater on the 30's and the 11th-stage heater on the 60's includes a channel-iron splash plate which is provided in order to effect better deaeration by breaking up the oxygen-bearing hot-drip returns as they enter the heater shell (see February installment). Oxygen liberated through the flashing process is vented to the condenser from whence it is drawn off by the dry-vacuum pump. The effectiveness of this provision is evidenced by the fact that the oxygen content of the incoming hot-drips is reduced from about 3 ppm to 0.01 ppm.

Condensers and Auxiliaries of House-Service Units

Condensers and auxiliaries for the new dc house-service units are completely new except for the condenser tubes. There are two sizes of dc units; No. 1 unit is 2000 kw and No. 2 and subsequent units, 2880 kw. The cylindrical-shell two-pass surface condensers are designed for $^3/_4$-in. tubes salvaged by redrawing old one-inch condenser tubes at a tube mill. The shell shown in Fig. 69 is built of welded copper-bearing steel plate with cast-iron water boxes and flat heads. Table XVII gives design data for these condensers and auxiliaries.

Because of the limited available space, steam air ejectors, see insert to Fig. 69, are installed for the dc units, although the Company has previously preferred reciprocating dry-vacuum pumps. These twin-element two-stage ejectors are integral with their single-pass inter-and-after surface condensers. With normal air leakage, one element in operation is sufficient to maintain the required vacuum. Ejectors operate on saturated steam at 220-250 lb per sq in. supplied from one of the plant pressure-reducing stations.

Semi-Outdoor Station Near Provo, Utah

Open-air steam power stations have long been advocated by some engineers and often discussed, but one is now to materialize at Provo, Utah, where the Utah Power Company will shortly start construction of a new station.

This plant will work in conjunction with a hydro-electric system and will consist initially of a 17,800 sq ft, three-drum CE boiler supplying steam at 435 lb, 760 F to an 18,750-kw (maximum) G-E turbine-generator. The unit will be fired by a CE forced-draft chain-grate stoker of 454 sq ft grate surface burning Utah bituminous coal. Because of the low ash content of the coals in the Utah district, and of the caking characteristics of some of them, it has been customary, when employing stokers, to use the underfeed type. Analysis of the local coal and the operating conditions in this instance, however, led to the recommendation of a chain-grate stoker with water-cooled front and rear furnace arches, as well as plain-tube water-cooled side walls. To verify this recommendation fourteen car loads of the coal were shipped to a plant in the middle West, where it was burned satisfactorily on a chain-grate stoker.

The steam generating unit will be carried on steel work which at the top will support a concrete slab carrying two induced-draft fans and a Thermix stack. An appreciable saving in building cost will be realized by enclosing only that portion of the unit which must be accessible constantly for operation. The entire upper portion of the unit will be exposed to the weather, with the exception of the water column which will have a separate enclosure. The setting will be suitably insulated and steel encased, and, together with all exposed piping and water-wall headers, will be properly waterproofed. The structure is designed to withstand a wind velocity of 100 miles per hour.

A. S. M. E. Dallas Meeting Papers

The program for the Semi-Annual Meeting of the American Society of Mechanical Engineers to be held in Dallas, Texas, June 15 to 20, is now complete. A number of simultaneous sessions on petroleum, transportation, machine shop, air conditioning, process, hydraulics and steam power are scheduled. Those having to do with power plants are as follows:

June 17, 3:15 p.m.

"Crack Residue Fuel Oils," by M. J. Hanlon; "Analyzing Variable Load for Diesel and Steam Stations," by G. C. Boyer; "Burning Gas, Oil, Coke and Sludges," by T. E. Crossan and A. J. Matherne, Jr.

June 18, 9:30 a.m.

Discussion of the A.S.M.E.-A.P.I. Unfired Pressure Vessel Code and Corrosion of Pipe Lines; "Chlorination of Circulating Water and Algae Control," by Robert R. Crowdus; "Heat Balance vs. Water Weighed Boiler Test," by E. L. McDonald.

2:00 p.m.

"Power and Heat Problems in the Sulphur Mining Industry," by C. L. Orr; "Fuel Injection Spark Ignition Oil Engines," by N. Fodor; "Diesel Fuels," by T. B. Rendel.

June 19, 9:30 a.m.

"Pulverized Texas Lignite in Large Central Stations," by N. G. Hardy; "Operating Features of the 1450-lb Deepwater Station," by H. G. Heibler; "Utilization of Natural Gas Fuel for Central Stations," by Elmer F. Schmidt.

Saturday, June 20 will be devoted to Engineers Day at the Dallas Exposition at which Dean A. A. Potter, President, American Engineering Council, is to speak.

Arrangements have also been made for a nine-day post-meeting tour to Mexico which will include a visit to Mexico City and numerous side trips therefrom to points of scenic and historical interest. This will be an all-expense trip costing $125 per person from Dallas and return.

Largest Chain-Grate Stoker

The new high-pressure steam generating unit to be installed at the Omaha steam station of the Nebraska Power Company will be fired by a CE forced-draft chain grate stoker 25 ft wide, 22 ft 9 in. long and weighing 171 tons. This is believed to hold the record as the largest single stoker of this type. It will serve a 275,000 lb per hr 1350 lb 3-drum CE bent-tube boiler having a water-cooled furnace and equipped with a regenerative air heater.

Embrittlement of High-Tensile Alloy Steels at Elevated Temperatures

The results of an investigation conducted on twenty-seven high-tensile alloy steels, to ascertain some of the factors influencing their embrittlement, when subjected to a temperature of 450 C (842 F), are contained in a paper by W. E. Goodrich before the current meeting of The Iron and Steel Institute (Great Britain). Nickel-chromium, chromium-molybdenum, nickel-molybdenum, chromium-tungsten-molybdenum and several types of nickel-chromium-molybdenum steels were included in a number of tests covering a period of 2400 hr. Evidence was obtained on the effects of the presence of a maintained tensile stress during the soaking period; of fluctuations of temperature; and initial heat treatment and variations in chemical composition. Strain-embrittlement tests were also carried out at 200 C (392 F) and at 450 C (842 F) on samples subjected to initial permanent tensile strains varying between 0 and 5 per cent. Hardness and micro-structural changes, resulting from the embrittlement treatments, were also examined.

As a result of the evidence obtained, it was considered that a mildly alloyed chromium-molybdenum steel was the most resistant to embrittlement. Employment of the highest tempering temperature, consistent with the production of the required tensile strength, was found to be advantageous. The presence of a maintained tensile stress of 22,000 lb per sq in., or exposure to fluctuations of temperature below 862 F, had no influence on the ultimate embrittlement produced by soaking at that temperature. The amount of embrittlement was not sensibly influenced by the presence of initial permanent strain up to 5 per cent, and no changes in Brinell hardness or microstructure could be found to account for any embrittlement produced.

It was found also that the higher the total nickel and chromium content of the steels, the greater was the molybdenum percentage apparently necessary to ensure relative freedom from embrittlement. Furthermore, an increase in the nickel content appeared to decrease the resistance to embrittlement of steels containing chromium and molybdenum.

Power Statistics for Sixteen Years Show Steady Improvement

The Power Resources Division of the U. S. Geological Survey has recently given out its report covering the production of electricity for public use in the United States during 1935. It also includes similar data, as well as the annual fuel consumption and average fuel consumption per kilowatt-hour for each year since 1919.

Based on reports from 3708 central stations, and 142 plants among electric railways, public works and manufacturing establishments, supplying power for public use, the total amounted to 99,398,000,000 kw-hr. The installed capacity represented was 36,133,112 kw of which 34,016,179 was in central stations. Of the total output, 40.2 per cent was produced by water power and 59.8 per cent by coal, oil and gas. For the fuel-burning plants there were used 34,807,000 short tons of coal, 11,393,000 barrels of oil and 125,239,000 cu ft of gas. The average consumption of coal and coal equivalent of other fuels per kilowatt-hour was 1.46 lb.

Over the period from 1919 to 1935 the total production of electricity increased from 38,921,000,000 kw-hr to 99,398,000,000 kw-hr, or more than two and a half times, but the relative percentages produced by fuel and water have remained relatively constant, within narrow limits, depending on certain wet and dry years when more or less water power was utilized. The most striking fact, which attests to the steady improvement in steam plant practice is that, although the output from such plants increased two and a half times, the coal consumption remained practically the same, or about 35 million tons. This is reflected in the decrease in coal per kilowatt-hour from 3.2 in 1919 to 1.46 in 1935. The fuel oil consumption in 1935 was practically the same as that in 1919, namely around 11 million barrels. The use of gas, however, increased from over 21 million cubic feet in 1919 to a maximum of 139 million cubic feet in 1931 and, after a marked decrease in 1932 and 1933, was back to approximately 125 million cubic feet in 1935.

Valves at Port Washington

In a paper before the recent Midwest Power Engineering Conference at Chicago, H. H. MacMillen of the Milwaukee Electric Railway & Light Company, discussed the valves used for 1350-lb pressure and 850-F steam temperature at the Port Washington Station. The bodies and bonnets of all gate valves are chrome-molybdenum steel castings with gates of the wedge type having stellited faces. Stainless steel is employed for valve trimmings. Special globe valves for the desuperheating lines, feedwater control, stop and check valves and automatic intercepting valves in the steam lines between the turbine and the reheater employ materials similar to those used for the gate valves. Studs for temperatures above 750 F are chrome-tungsten and those for sevice below 750 F are of chrome-nickel steel. All studs for high temperature were calipered before and after pulling up, to insure even stresses in the joints.

Announcement has been made that the Twelfth National Exposition of Power and Mechanical Engineering will be held at the Grand Central Palace, New York, on November 30 to December 5, coincident with the Annual Meeting of the American Society of Mechanical Engineers.

Plans are now being completed for the Fourth Annual Convention of the Edison Electric Institute to be held at the Municipal Auditorium, St. Louis, Mo., June 1 to 4, inclusive. Six general sessions are scheduled at which addresses will be given by leading utility executives on topics of immediate and vital importance to the industry and, in addition, a number of outstanding speakers from other fields will discuss matters of broad national importance.

Determining Oxygen in Boiler Feedwater

New Method Eliminates Titration

By A. C. DRESHER

Chemical Engineer,
Cochrane Corp., Phila., Pa.

In the temperature method here described, which is a modification of the Winkler Test, many variables, such as titration, strength of thiosulphate and separate deduction for oxygen in the reagents, are eliminated. It is based on the definite relation between the amount of oxygen in the feedwater and the temperature at which the blue color of the iodometric starch reaction appears, and is accurate as well as simple.

THERE is perhaps no feedwater test in regular use in the boiler plant that has been under such close scrutiny as the Winkler Test for the determination of dissolved oxygen. The importance of accurate determination is necessary in the control of corrosion of boilers, economizers, etc. and in the standardization of deaerating equipments. Numerous investigations of the Winkler Test have been conducted by committees and equipment manufacturers, which research has led to a better understanding of the technique necessary for the degree of accuracy demanded by present-day boiler plant operation. Two notable papers[1,2] have been written pointing out the precautions necessary and outlining two different procedures for the estimation of traces of dissolved oxygen.

The need for accuracy is indisputable but there is also a very definite need for simplifying the procedure so that the many variables common with the present procedure may be removed. This has been accomplished by the temperature method described below. In following this the variables of titration, strength of thiosulphate solution and the separate deduction for oxygen in the reagents are eliminated without sacrificing accuracy. The method, therefore, should become popular with operating engineers who look upon former methods as laboratory procedures.

The temperature method is a modification of the standard Winkler test and is based on the fact that there is a definite relation between the amount of oxygen in the feedwater and the temperature at which the blue color of the iodimetric starch reaction appears. This relationship is constant and once determined can be used as a basis for accurately measuring the oxygen content of the sample. Fig. 1 illustrates this relationship with two types of starch as indicators and was previously discussed in the article by J. D. Yoder and A. C. Dresher.[1]

As an illustration of the effect of temperature on the results to be obtained in the Winkler Test it is clear from Fig. 1 that if a sample of water were taken and tested at 120 F, using Baker's c. p. soluble starch as the indicator, then the reading would be zero despite the fact that the sample might have contained as much as 0.18 cc per liter, or if the sample were tested at 100 F, the indication would be zero with the presence of 0.06 cc of oxygen per liter. It is apparent therefore that the temperature of titration in the estimation of oxygen is an all-important factor and in this method advantage is taken of this relationship since it is definite and constant for any fixed amount of oxygen in the feedwater, and once determined can be used as a basis for future tests.

The procedure described below in detail takes into account the fixing of the sample by the regular reagents in the same manner as in the older procedures and the addition of the starch indicator at a temperature at which there is no formation of blue color. The gradual decrease in temperature brought about by cooling results in the appearance of the blue color and the temperature observed at this point. By reference to the curve, Fig. 2, the oxygen content of the sample is observed. For example, if the appearance of blue color was first observed at 90 F, then the oxygen in the sample is 0.025 ml per liter.

Comparison with Titration Method

The temperature method has been checked against carefully conducted titrations and the two methods were found to give very close results. In order to eliminate differences due to varying oxygen content of the samples, the oxygen was first determined by the temperature method after which the sample was titrated at temperatures below 85 F. After correcting the titration results for the oxygen added with the reagents, the results were found to check within 0.002 ml of oxygen per liter.

The Method

The sample of water is taken following the precautions already pointed out in the article by J. D. Yoder and A. C. Dresher and it is assumed that the reader is thoroughly familiar with the procedure. The sample is taken at approximately 115 F, the Winkler reagents

[1] "The Winkler Test for Determining Oxygen in Boiler Feedwater" by J. D. Yoder and A. C. Dresher, COMBUSTION, April 1934.
[2] "The Determination of Traces of Dissolved Oxygen by The Winkler Method" by M. C. Schwartz and W. B. Gurney, A.S.T.M. Vol. 34, Part II—1934.

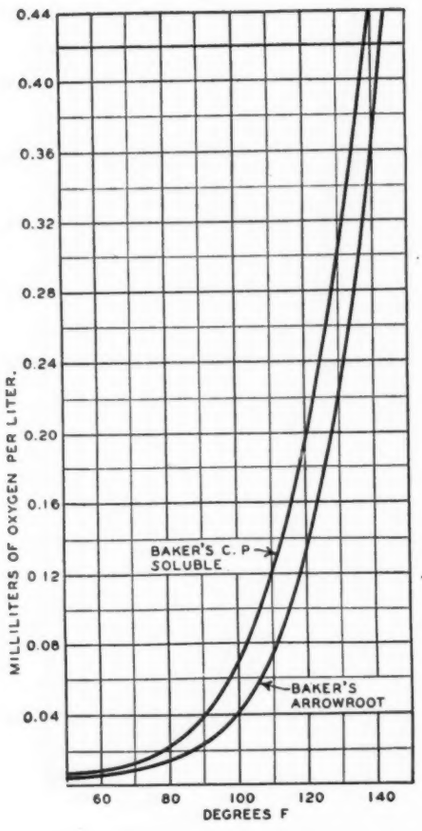


Fig. 1—Temperature at which blue color forms with various amounts of oxygen

added and after fixing the sample the following procedure should be carried out:

1. Rinse out the 250-ml Erlenmeyer flask with a portion of the sample.
2. Pour approximately 200 ml of the sample into the Erlenmeyer flask. The operator may judge the amount, or use a 200-ml volumetric flask.
3. If the temperature of the sample is less than 115 F, warm the sample to this temperature. The flask may be heated over a hot plate or burner or by placing it in a container of hot water; stirring the sample with the thermometer. If the oxygen content of the sample is consistently low, around 0.02 ml per liter, it is not necessary to heat the sample to 115 F. It is merely necessary to have the temperature of the sample about 10 deg higher than that at which the first blue color forms; see Fig. 1.
4. Partly fill the 385-ml evaporating dish with cold water, adding several small pieces of ice if necessary.
5. Add approximately 1 ml of starch solution to the sample.
6. Place the Erlenmeyer flask, containing the sample, in the evaporating dish, and *stir constantly* with the thermometer until the first trace of blue color is observed.
7. Read the thermometer.
8. Refer to the curve Fig. 2 and at the observed temperature trace upward until the curve is reached, then to the left, and read the "true" oxygen content of the sample. The curve has been corrected for the oxygen added with the reagents, i.e., 0.015 ml of oxygen per liter.

Interference

Interfering chemicals in the water supply, or interference due to contaminated reagents, has been discussed in the previous article.[1] The temperature method may be used to test for either "positive" or "negative" interference that may be present in the water, or in the solutions. When testing for interference the sodium hydroxide-potassium iodide solution is added first, followed by the hydrochloric acid, and after thorough mixing to neutralize the sodium hydroxide, the manganous chloride solution is added. In running an interference test it is not necessary to protect the sample from the air while the reagents are added; and if the purity of the reagents is being determined use distilled water in place of feedwater.

Testing for Interference

1. Rinse out the 200-ml volumetric flask with a portion of the sample, and fill to the mark.
2. Pour the measured sample into the clean Erlenmeyer flask.
3. If the temperature of the sample is below 100 F, warm to this temperature.
4. Add 0.15 ml of 0.01 *N* iodine solution, and stir thoroughly.
5. Add approximately 1 ml of starch solution, and stir.
6. Cool the sample as described under "The Test," with constant stirring, and note the temperature at which the first faint blue color forms.

If either type of interference is absent, the sample will turn blue at 91 F. If "positive" interference is present, the sample will turn blue at a higher temperature; while "negative" interference is indicated by the formation of a blue color at a lower temperature.

It should be noted that the oxygen of the sample and of the reagents does not liberate iodine, as the Winkler Test reagents do not react when added in the order given; 0.15 ml of 0.01 *N* iodine solution to a 200-ml sample is equivalent to 0.042 ml of oxygen per liter. Fig. 2 shows 0.027 ml of "true" oxygen per liter at 91 F.

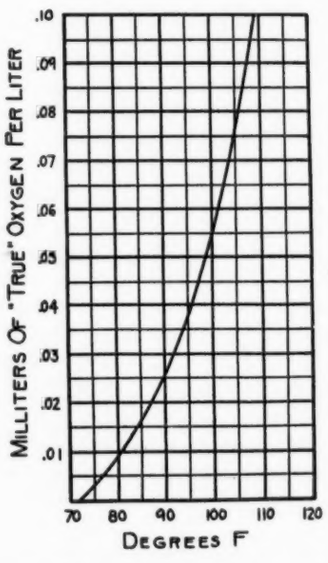


Fig. 2—Temperature at which faint blue color forms gives "true oxygen" of sample. Use Baker's c. p. soluble starch

The "total" oxygen, or the oxygen of the sample plus the oxygen of the reagents, is 0.027 plus 0.015, or 0.042 ml of oxygen at 91 F.

Equipment

Solutions—The solutions should be made up to the following strengths, using c. p. chemicals and distilled water:

1. Manganous Chloride—40 grams of $MnCl_2.4H_2O$ dissolved in water and diluted to 100 ml. Filter the solution if it contains suspended matter. Use 1 ml to a 280-ml sampling bottle.
2. Sodium Hydroxide-Potassium Iodide—42 grams of sodium hydroxide dissolved in water, add 10 grams of potassium iodide and dilute to 100 ml. If the solution is cloudy, allow it to settle and pour off the clear solution. Use 1 ml to a 280-ml sampling bottle.
3. Concentrated Hydrochloric Acid—Use 5 ml to a 280-ml sampling bottle.
4. Starch solution should be prepared fresh each day that tests are to be run. To make a solution, free of lumps, use 2 grams (approximately $\frac{1}{2}$ teaspoonful) of Baker's c. p. soluble starch, mix into a paste with a little cold water, add 100 ml of boiling water and stir thoroughly. If possible, the solution should be boiled with constant stirring for approximately $\frac{1}{2}$ min. Use about 1 ml to a 200-ml sample.
5. Iodine Solution—0.01 *N*, 1 ml to a 200-ml sample is equivalent to 0.28 ml of oxygen per liter.

In addition to the proper sampling cooling coil arrangement, the following equipment is required:

1. Sampling bottle, glass stoppered, 280-ml capacity.
2. Pipettes, one 1 ml graduated in 0.01 ml three 1 ml, and one 5 ml.
3. Erlenmeyer flask, 250 ml.
4. Thermometer, 40–120 deg F, graduated in degrees.
5. Evaporating dish, 385 ml.
6. Volumetric flask, 200 ml.

The simplicity of making this test, coupled with its accuracy should appeal to boiler plant operators and chemists. In titrating by the customary methods, overrunning titration by a single drop may represent an error of 100 per cent in the final estimation. The temperature method avoids this because the blue color appears slowly and an error of a few degrees in reading the thermometer makes no appreciable error in the final determination. The elimination of the titrating agents susceptible to deterioration is also a step in advance and gives more assurance as to accuracy and reliability.

Report on Professional Development

Publication of the third annual report of the Engineers' Council for Professional Development makes available to engineers and educators a record of the activities of this body. It provides information on the organization, purposes, policies, personnel of the Council and the work of its four major committees on student selection and guidance, engineering schools, professional training and professional recognition.

The report of the Committee on Student Selection and Guidance, of which Dean R. L. Sackett is chairman, deals principally with tests designed to supplement methods of selecting students for engineering colleges. Plans for putting into effect its program of accrediting engineering schools are discussed in the report of the Committee on Engineering Schools.

Appendices contain a selected bibliography of engineering literature; a preliminary survey of university extension facilities, including a general description of the scope of the courses and the educational institutions giving these courses; also a digest of the registration laws in 35 states.

Boilermaker as an Employee within Workmen's Compensation Statutes

By LESLIE CHILDS,

Attorney, Indianapolis, Ind.

IN the operation of a steam plant the services of a boilermaker may be required from time to time in connection with repair work where the plant is not of sufficient size regularly to employ such a craftsman, the custom of calling in one as required is followed. However, in view of the wide application of workmen's compensation statutes, the employer may well have a care as to the employment status of such a workman. For, by merely assuming that such employment is casual and not covered by statute, an employer may unwittingly expose himself to substantial loss if the workman meets with an accident.

The courts are not completely in accord as to circumstances under which employment of this character will be casual, but the following case will serve as an example of judicial reasoning in a situation of this kind.

Here the defendant operated a battery of four boilers in connection with a mine. He did not have a boilermaker on his payroll, but hired outside help when the boilers required overhauling or repairing. On the occasion here involved, he hired the claimant to put a patch on one of the boilers. The latter was an expert boilermaker and was hired by the hour. He had no shop of his own, and used some of his tools and some belonging to the defendant in doing the work. He hired a helper of his own choosing who was also paid by the hour by the defendant. The latter exercised no supervision over the work, beyond informing claimant what was desired.

After claimant had worked several hours, a piece of metal flew into his left eye while he was chipping the boiler shell. The accident resulted in loss of the eye, and in due time he claimed compensation, therefore, under the workmen's compensation statute of the state in which the accident occurred.

The defendant denied liability on the ground that claimant's employment did not bring him within the statute, and set up the following specific exemption provision therefrom:

"Third: Employments which are but casual or not incidental to the operation of the usual business of the employer."

Under the foregoing commonly met with provision in statutes of this kind, the defendant contended that claimant's employment was clearly casual; that the cause of the hiring was an accidental, unexpected occurrence of a boiler springing a leak; that the hiring was for a limited definite time of a few hours to do a specific kind of work, and that it was not incidental to the operation of defendant's usual business of mining.

Upon a hearing, however, the compensation commission found in favor of the claimant and awarded him a sum totalling $2,304.98. This award was affirmed by the lower court and the defendant appealed. Here the higher court in reviewing the record, in part, said:

(*Continued on page 36*)

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(*Continued from page 35*)

Language of the Courts

"The evidence shows that boilers in use sooner or later require repairing; that the boilers of the defendant needed repairing about once a year and that the repairing is a part of the usual routine business . . . ; that claimant had been repairing boilers for the defendant . . . off and on for two or three years prior to the accident and altogether had put about four patches on them; . . . the work would require only a few days and, of course, claimant's employment by defendant was not continuous . . . ."

Following the foregoing review of the record, the court turned to the question of whether claimant's employment should be deemed casual. Here, in quoting the rule from another case, the court continued:

"It was not the intention of the Legislature to exclude from the operation of the act any one engaged in work necessarily required in the usual prosecution of such industry, and that the duration of such employment or the infrequency of the same ought not to control the courts in determining whether the employment was casual or otherwise. If the employment was essential and was required in the prosecution of the regular business of the industry, the industry, in order to carry out and effectuate the purpose of the act, should pay for any injuries sustained. . . ."

Then in conclusion the court reasoned:

"In the case at bar the evidence shows that defendant's boilers would get out of repair and that it was necessary to keep them in repair in order to operate his mine. That being true, the work claimant was engaged in was not casual, although such repairs were not required at regular intervals and no one knew in advance when such employment would be required. . . the judgment should be affirmed and it is so ordered." (*76 S.W. (2) 706*)

The foregoing case was carefully reasoned by the court, and the holding announced is supported by much authority, though, as noted in the beginning, the courts are not in accord on the question of what constitutes casual employment, and it is probable that in some jurisdictions the defendant would have prevailed on the facts of this case. However, the case constitutes a striking example of the importance of the exercise of due care on the part of employers in situations of this kind. Otherwise, such hiring may involve risk. The case reviewed may well be kept in mind when employment contracts of this character are being entered into.

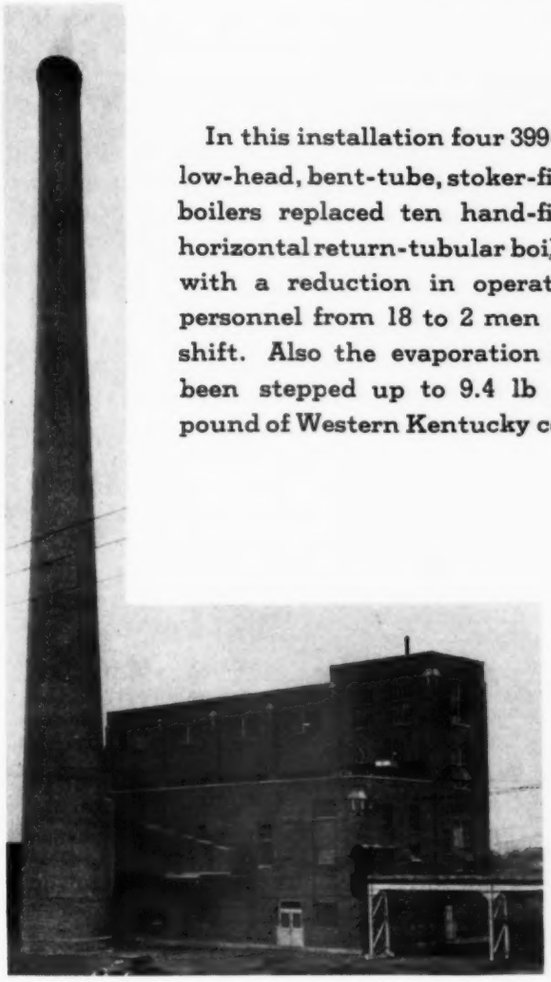
Feedwater Papers at A.S.T.M. Meeting

A large number of technical papers and reports are scheduled for presentation at the Annual Meeting of the American Society for Testing Materials to be held in Atlantic City, June 29 to July 3, inclusive. Of particular interest to power plant men will be the session on water. This will include the report of the Joint Research Committee on Boiler Feedwater Studies and papers dealing with the rate of reaction of sodium sulphite on dissolved oxygen, the use of solubility data to control the deposition of sodium sulphate and the effect of solution compositions on the failure of boiler steel under static stress.

New Boiler Plant Effects Savings at WATHEN DISTILLERY

By E. B. RODMAN, Res. Mgr.
National Distillers Products Corp.

In this installation four 399-hp low-head, bent-tube, stoker-fired boilers replaced ten hand-fired horizontal return-tubular boilers with a reduction in operating personnel from 18 to 2 men per shift. Also the evaporation has been stepped up to 9.4 lb per pound of Western Kentucky coal.



THE Wathen Branch of the American Medicinal Spirits Corporation, Louisville, Ky., a unit of the National Distillers Products Corporation, has recently placed in operation, a boiler plant that is effecting a marked savings in fuel and labor and, at the same time, providing ample capacity for the growing steam demands.

For many years the steam for this distillery was supplied from an old boiler house having ten hand-fired horizontal return-tubular boilers. Most of these boilers were set only four feet from the ground to the bottom of the shell which resulted in dense black smoke most of the time. On each shift 18 to 20 men were required to handle the coal and fire these boilers and they were often unable to maintain proper steam pressure to the distillery.

In view of this situation, Sanderson & Porter, Consulting Engineers of New York, were engaged in 1934 to draw up plans for a new boiler plant. The contracts were awarded, construction work started in January 1935, and the new boiler plant was placed in operation last October.

The new plant contains four 399-hp CE low-head, bent-tube boilers, set singly, and each capable of generating 33,000 lb of steam per hour at 125-lb gage operating pressure. The boilers are designed for 160-lb gage without superheat and have fusion-welded drums, the front and mud drums being 36 in. diameter, and the rear drum 48 in. diameter. They are set 11 feet from the floor to the center of mud drums.

Each boiler is fired by a turbine-driven four-retort Westinghouse stoker, equipped with an underfeed and overfeed section, the lower end of which is supported and slides upon an ash discharge plate extending outward beneath a water-wall that is connected into the boiler circulation. The lower portion of the water-walls to a height of $3^1/_2$ ft above the stoker discharge plate is covered with CE furnace blocks cast integral with the tubes to protect them from erosion due to the movement of the ash being discharged continuously from the stoker.

The rate of ash discharge is controlled by varying the height of the opening between the ash discharge plate and the water-walls. This opening is adjusted to be kept full of ash so that the upper surface of the bed of ashes is held back by the water-wall, and the fuel resting on top of the ash is retained in the furnace until it is consumed. Coal feed indicators, calibrated in pounds of coal per hour per retort, are provided.

Located on the firing floor in front of each boiler is a Clarage forced draft-fan with a vortex inlet damper, each fan being driven by a steam turbine. The blowers are connected to the stoker windbox by individual and inter-connecting air ducts.

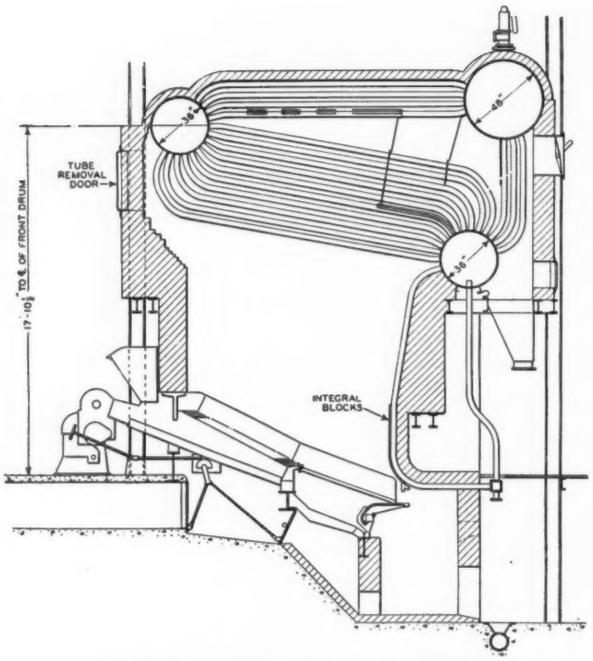
Soot hoppers with dust-tight gates are built into the setting under the rear pass so that the soot accumulation can be periodically discharged to the ash-handling system which is directly below.

The boilers are fitted with Consolidated safety valves, Yarway blowoff valves and Reliance gage columns with high and low water alarm.

The coal handling system consists of a track hopper adjacent to the boiler house with a bucket elevator delivering coal from the track hopper to an overhead bunker from which it is spouted to the stoker hoppers.

The ash handling equipment in this plant was furnished by the United Conveyor Corporation. In this system the ashes are conveyed from the ashpit through a "steamatic" suction pipe line conveyor to a carload capacity glazed tile storage tank located just outside of the power house from which point the ashes can be loaded either into railroad cars or trucks.

In order to facilitate handling of the material from the ashpits into the conveyor system, a grid feeding hopper is located in front of each ashpit door, of which there are



Section through boiler and setting

two per boiler. The feeding hoppers are also provided with side shields to prevent any spillage of the ashes or cinders, and this makes for cleanliness in the ash tunnel. Since this is a totally enclosed type of conveyor system, the ashes are delivered into the storage tank without creating any dust nuisance inside or outside of the power plant.

The conveyor capacity is ample to handle the volume of ash produced in this plant with sufficient reserve capacity to take care of probable future expansion.

Approximately 85 per cent of the water fed to the boilers is makeup. The raw water and the condensate returns are heated, deaerated and treated in a Neckar System tank which has capacity for 3000 boiler horsepower. From this treatment tank turbine-driven centrifugal boiler feed pumps supply water to the boilers with less than 1 grain hardness and at a temperature of 234 F, or above. In case of a failure of make-up water supply there is available at all times for emergency use a supply of treated water that will keep the boilers operating at normal rating for about two hours.

With the system of feedwater treatment installed there is withdrawn from the boilers at all times a small amount of water which keeps the concentration constant without requiring any intermittent blowdown through the regular boiler blowoff valves. This continuously withdrawn water flows at low pressure into the treatment tank where it improves the chemical treatment taking place and greatly reduces the amount of chemicals which have to be added. At the same time this recirculation of withdrawal water accomplishes deaeration and higher temperature of the feedwater then would be obtained from low pressure steam alone.

Through this recirculation, a sulphate carbonate ratio of at least 3:1 is maintained and is accomplished by conserving the sulphates taken in through the raw water. The only water lost in keeping the proper amount of concentration in the boiler is a small portion which is drained off from the water that is being withdrawn from the boiler to the tank. This drained water is further concentrated by flashing which reduces its temperature to approximately that of the feedwater going to the boiler feed pumps.

The raw water is added to the system through a proportioner type Bailey meter which both indicates and integrates the amount of flow and controls the feed of lime and soda ash to the treatment tank in proportion to this rate of flow. The chemicals are pumped from a separate chemical tank into the treating zone of the treatment tank by a small triplex pump.

Normal operation has been to keep the boiler water alkalinity at 500 ppm with a sulphate ratio maintained between 3:1 and 5:1. Results have shown that this system makes it possible to operate the boilers at 250 per cent rating without the formation of scale. There has been no corrosion or deposits in the feed lines and the steam delivered by the boilers is of excellent quality.

The boilers and stokers are automatically controlled by a complete Bailey system which regulates the boiler dampers, the stoker speed and the forced-draft air supply.

The new plant is burning Western Kentucky coals, and the evaporation has been stepped up to 9.4 lb per pound of coal. For the present three boilers easily carry the load and only two men are required per shift to operate the entire plant which is a model for cleanliness.

Many Applications for Professional Engineers' Licenses Pending

The New York State Board of Examiners for Professional Engineers now has before it over three thousand applications, filed before April first in order to be eligible for the June examinations. It will probably be impossible for the Board, working under pressure, to handle this unprecedented volume of applications in two months, and many of these may have to be held over for assignment to the following examinations in January 1937. Most of the new applications are from men occupying engineering positions in industry and research.

In order to qualify for the January 1937, examinations, applications must be received before November first.

The final dead-line date for the filing of applications under the present examination requirements is January 1, 1937. All applications received after that date will be considered under the new rules authorized by the Registration Law, with more exacting educational, experience and examination requirements. Graduates from approved colleges of engineering, as well as others, will be required to take the full prescribed written examinations (two days) without any partial exemptions. Candidates who are not graduates of approved engineering schools will have to show twelve years of satisfactory engineering experience before admission to the same written examinations.

New York State now has 10,000 registered professional engineers in good standing, and 3750 registered land surveyors, making a total of 11,079 after deducting duplications. Since the enactment of the Registration Law in 1920, the State Board has licensed 13,100 professional engineers and 4900 land surveyors, or a total of 14,500 after deducting 3500 men licensed to practice both.

Application of Colloidal Chemistry to Boiler Water Conditioning

By L. DREW BETZ
and ROBERT T. SHEEN
Chemical Engineers, Philadelphia

Organic materials have long been used either singly or in combination with various inorganic precipitants for correction of boiler feedwater. Articles have been published from time to time telling of the values to be attained by the use of such materials, some claiming they could be used as "cure-alls," and others recognizing that organic materials do have a definite value in this field in conjunction with the use of inorganic precipitants (*1*).[1] On the whole, the lack of quantitative data is quite marked, and the action of this class of materials has been more or less obscure. The present paper, given before the Chemist's Sub-committee of the Edison Electric Institute, does much to clarify this situation particularly with reference to a class of colloids that possess a definite reaction with calcium and magnesium salts.

COLLOIDS are in reality a state of matter and not an individual substance. Many chemicals can be placed in the colloidal state, but by no stretch of the imagination can one assume that simply because a substance is of colloidal nature that it is suitable for water purification. Soaps, glue and many other substances are common illustrations of true colloids. Many metals can be placed in the colloidal state and yet are unfitted and have no value in this field.

The term, "colloid," was first suggested by Graham in 1861, and is derived from the Greek word meaning "glue." It was adopted for those substances which would not diffuse with the usual rapidity in water. Upon further investigation, it was found that these materials did not actually ionize when placed in solution but the substance as a whole was dispersed. Particles of a crystalloid in solution cannot be seen through a microscope or an ultra-microscope, but dispersions of a colloidal substance can be detected by the use of an ultra-microscope by what is commonly known as the Brownian movement. There are fairly clear lines of demarcation between true solutions, colloids and suspensions based on particle size. Units of length commonly employed in measuring colloids are the micron, and the millimicron. The former is the thousandth part of a millimeter and the latter the millionth part. Colloids, as a rule, fall between 0.1 millimicrons and 100 millimicrons. It further becomes evident that one material must be dispersed in another material before the colloidal state is attained. As matter exists in the three different forms; solids, liquids and gases, there are nine possible combinations. The type of colloidal system that has an application to correction of boiler feedwater is limited to the dispersion of a solid in a liquid.

In this system colloids exist in two forms, sols and gels. A colloidal solution, or dispersion is called a sol, consisting of a large number of tiny particles termed micelles evenly dispersed or suspended in a medium. When these particles agglomerate or precipitate to form larger particles, the resulting precipitate is called a gel. A sol is essentially a solid dispersed in a liquid, while the gel is essentially the liquid dispersed in a solid. The change from a gel to a sol is usually called *peptization* and the reverse change from a sol to a gel is termed *pectization*. Colloid chemistry is really a chemistry of surfaces, and reactions taking place with colloids must be interpreted in this light. If a cube, one cubic centimeter in size, were evenly divided into cubes one millimicron on each side, the surface exposed would increase from six square centimeters to 1.48 acres.

All particles in a colloidal state possess an electric charge. This can be proved by placing a pair of electrodes in a colloidal dispersion and passing a charge through the solution. The colloidal particles plate out on the electrode with opposite charge to that possessed by the particle itself. The system of solids dispersed in water can be further sub-divided into hydrophobic, or water-hating colloids, and hydrophilic or water-loving colloids. A hydrophilic colloid differs from a hydrophobic colloid in that each individual particle is encased by a sphere of water, commonly called the shell of hydration. Tannin, starch and certain gums are hydrophilic colloids. Silicates present in the colloidal state form hydrophobic colloids.

When a material is said to be a negative colloid or a positive colloid, it must not be inferred that each colloidal particle carries only a single unit of electrical charge. As a matter of fact, each particle carries several layers of charges, each of which is of the same sign. The total number of changes in a given volume of colloidal dispersion increases as the particle size decreases. In other words, the number of charges increases with the area exposed. The greater the peptization, the finer will be the particle, the greater the area exposed and the higher the charge it will carry. This has a direct bearing on a study of these reactions under the temperature of boiler operation.

[1] Numbers in brackets refer to Bibliography.

If a pectizing agent is added to a stable colloidal sol, the electrical equilibrium is disturbed, allowing several of the colloidal particles to coagulate together to form a larger particle and consequently settle out of solution. This is equivalent to transferring the colloid from the sol state or dispersed form to a gel state or coagulated form.

Linder and Picton (*2*) were the first to give a chemical explanation of the precipitation of sols by electrolytes and to show that the precipitated gel carried down the ion of the added electrolyte which was of opposite sign of charge to that carried by the micelle. Other colloidal authorities (*3*) point out the work of other investigators in confirming this theory and further show that polyvalent precipitating ions are held tenaciously in the gel.

The colloids that have found general application in the field of water conditioning may be classified as protective type colloids and reactive colloids. Their action is somewhat different and the general tendency to class all colloids used in water purification together has led to confusion and misunderstanding. A protective colloid protects various crystalline precipitates formed in the boiler water by attaching themselves to the particle of the precipitate, acting in this manner to prevent crystals from adhering to heating surfaces when settling from solution. The reactive type possesses the ability to react with or remove from solution various incrusting solids such as calcium or magnesium. It is not to be implied that a straight chemical reaction can be written showing a given molecular or polymolecular weight of colloid reacting with a given molecular weight or calcium or magnesium, or in other words, that the reaction proceeds in stoichiometric fashion. The important point is that the reaction does not proceed in stoichiometric fashion and that the ratio is variable, and for this reason can probably be termed as a colloidal reaction.

Starches and tannins may be classified as protective colloids and have recently received attention since the work at the Naval Academy by Solberg and Adams (*4*). Starch is a hydrophilic or water-loving colloid, negatively charged. The particle size is rather large and it may be peptized by several methods. One is to treat starch with hydrochloric acid and dry the reaction product, which will then readily disperse in water. It may also be peptized by ultra-violet light and by several other complicated chemical processes. Starch will be pectized or precipitated by the addition of small amounts of barium hydroxide, lead acetate or tannic acid but will not selectively adsorb calcium or magnesium from solution in water. Its precipitation in boiler water is caused by mutual coagulation of the starch particles with insoluble inorganic precipitates which have been formed in the water by the reaction of some conditioning chemical.

In the precipitation of incrusting solids with phosphates or carbonates, the crystal itself passes through a colloidal size in reaching sufficient size to settle from solution. It is during this time that a reaction between the precipitate and the starch or other protective colloid occurs. The precipitated phosphate or carbonate crystals in the colloidal state carry a positive charge and the negatively charged starch will precipitate on the phosphate particles, not the phosphates on the starch, and be held by the attractive forces of the two opposite charges. As the charge carried by the starch particles on the micelle are relatively few, several particles of starch will adhere to an individual crystal. In an agglomeration of such a precipitate a number of crystals will interlock with particles of starch enmeshed in the coagulum. Instead of a crystalline precipitate being entirely protected by a colloid shell, there is a crystalline shell containing spots or particles of the colloid. While this weakens the crystal structure when deposited on a heating surface, there is, nevertheless, a possibility of the resulting coagulum interlocking to form a deposit. All crystalloids used in water purification will adhere to a heating surface in greater or lesser degree depending on the type and character of the precipitate. The use of starch or tannin lessens the possibility of such deposits but they have not proved to be totally satisfactory under all conditions. It is generally believed that starch is unstable under higher boiler temperatures, breaking down to liberate organic acids.

Tannin has long been used in conjunction with inorganic precipitating agents. These are extracted chiefly from chestnut bark, oak bark and quebracho. Tannins can also be peptized with acid and is stable in all proportions with water, acetone and acetic acid. The facility of dispersion of tannin is due to the ease of wetting of the tannin powder by the dispersing medium.

Alexander (*5*) states that various inorganic salts have little effect on the stability of tannin sols with the exception of hydroxides of heavy metals, for example, barium hydroxide. The addition of relatively large amounts of caustic soda or other alkalies to the tannin sol will not affect the stability of the sol. Tannin is likewise a hydrophilic colloid and carries a negative charge. Its function, however, is similar to that of starch in that it acts protectively and is not precipitated or pectized by calcium or magnesium ions. The negatively charged tannin particles precipitate on the positively charged suspended solids in the boiler water, this resulting from the reaction of inorganic materials present with the various incrusting solids. There is some tendency of tannin to break down under higher pressures with liberation of corrosive organic acids. There have been some arguments for the use of tannin for removal of dissolved oxygen but no quantitative data have been presented up to the present time. Tannin has not proved as advantageous as sodium sulphite for this work and the latter is to be preferred as it can be easily controlled.

The second group of colloids finding use in the field of boiler feedwater purification may be classed as reactive types and belong chiefly to the laminaric acid series; laminaria stenophyllia and laminaria digitata being common illustrations of this family of colloids. These colloids are hydrophilic and carry a negative charge, and may be peptized to various degrees with alkaline sodium salts. The amount of peptizing agent employed determines to a large extent the particle size of the sol. When calcium or magnesium ions or any other polyvalent positive ions are added to a system with this sol present, a selective adsorption of the calcium and magnesium ions occurs with a removal of these ions from solution. An ion of calcium or magnesium will be removed for each two negative charges carried on the micelle and each particle is therefore capable of taking up several calcium or magnesium ions. These ions act as a pectizing agent, agglomerating the sols to form a gel and thus an actual removal of calcium and magnesium

is effected in an organic form and the resulting precipitate has no tendency, due to its character, to adhere or bake to a heating surface. The reaction is not completely effective at room temperature and the quantity of calcium and magnesium removed per unit of colloid sol increases with temperature up to at least 230 C. In other words, the higher the pressure under which the reaction takes place, the greater the amount of calcium and magnesium or other polyvalent and positive ions will be precipitated per unit of colloid introduced. At 212 deg one part of colloid will remove approximately 0.1 to 0.2 parts of hardness expressed as calcium carbonate. At 125 to 150 lb pressure, reactivity has increased to 0.7–1.0 parts of calcium carbonate per part of colloid sol. At 300 lb, the reactivity has increased to approximately 2 parts of calcium carbonate per part of colloid. Above this boiler pressure, or at approximately 220 C the solubility of the precipitated or pectized gel, having completed its reaction with calcium and magnesium, is less soluble than tri-calcium phosphate at this same temperature. Below this pressure, phosphates will act preferentially to the colloid in removal of calcium and magnesium and above this pressure, the colloid will act preferentially to the phosphate. Therefore, above this pressure, soluble phosphate can be used as a method of control for colloidal conditioning. Reactivity of the colloid at 400 lb pressure is approximately 2.2 to 2.5 parts of calcium carbonate per part of colloid. These reacting ratios are obtained from a study of data procured from the operation of many plants.

The pectized gel of calcium and magnesium by virtue of the enormous surface exposed, possesses the ability to remove suspended solids to a high degree. In many cases, it is desirable to employ other precipitating agents such as carbonate or phosphate in conjunction with the colloid, not only for the softening value of these agents but also for the peptizing value on the colloid sol. The phosphate possesses a higher peptizing value than carbonate and for this reason is preferred.

One criticism directed at the use of a reactive colloid has been that excess colloid in the water cannot be determined by direct analytical methods. With low-pressure installation, quantities of material used, together with a chemical balance of the boiler water as a whole allow an efficient control. Above 300 lb pressure, phosphate can be employed and a phosphate method of control utilized.

Research work is now in progress on solubility and further reacting values of these organic reagents at higher pressures to confirm results obtained in actual practice. It will be appreciated that novel lines of procedure must be followed to obtain such results and the methods required are somewhat different from methods that have been employed in the past on solubility studies. The publication of progress reports on this method is contemplated.

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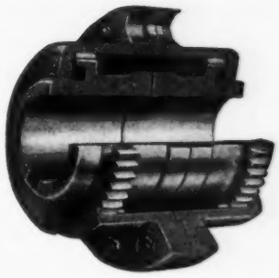
Specifying



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STEAM ENGINEERING ABROAD

As reported in the foreign technical press

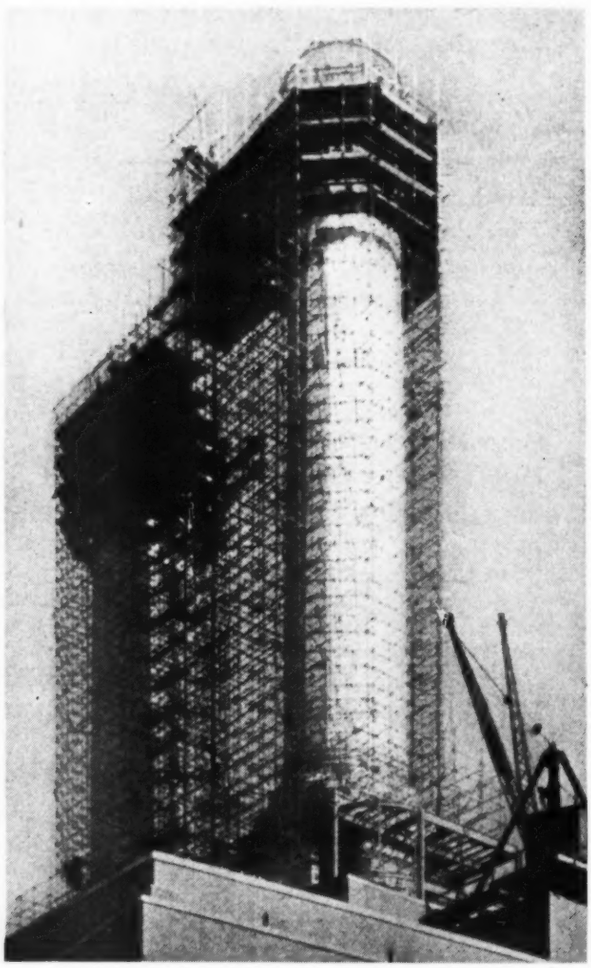
Reinforced Concrete Chimneys

A number of the newer British power stations are employing reinforced-concrete chimneys, according to an article by B. Frisby in the April issue of *The Power and Works Engineer*. Among those described are Fulham, Clarence Dock, Battersea, Deptford and Dunston, their principal dimensions being as follows:

Station	Internal Diameter Base	Internal Diameter Top	Height from Ground To Top
Battersea	28 ft 2 in	22 ft	352 ft
Deptford	20 ft 9 in.	17 ft 9 in.	285 ft
Dunston	18 ft	15 ft	259 ft
Clarence Dock	28 ft	25 ft	335 ft
Fulham	21 ft 6 in.	18 ft 3 in.	218½ ft

Because of sulphur in the coal and the consequent presence of SO_2 in the flue gases, which would attack the concrete and form a compound of gypsum and calcium aluminate, special acid-resisting linings are employed. The space between the concrete and the lining is either left free for the circulation of air or filled with crushed slag or asbestos. The lining is usually divided into independent sections or barrels, each supported on the concrete shaft by a continuous corbel.

An exception is to be found at the Fulham Station where the gas is washed and the temperature leaving the washers is about 180 F. Here the chimneys are unlined but will be treated on the inside with two coats of magnesium silico-fluoride and three coats of acid-resisting paint.



Stacks under construction at Fulham Station

Marine Boiler Installations

Some interesting particulars concerning the boiler installations of modern liners are contained in a paper by Rear Admiral W. N. Whayman, read before the Institution of Naval Architects (Great Britain) on April 2nd and reproduced in *Engineering* of April 17th. Most of these vessels employ steam pressures from 400 to 450 lb and steam temperatures from 650 to 740 F with the conventional marine type of boiler. The number of boilers and the total evaporation varies, of course, with the size of the vessel, the maximum being the "Normandie" with 29 boilers and a total evaporation at normal load of 1,360,000 lb per hr, or an average of 46,896 lb per unit. The largest units are those in the "Conte di Savoia" (Italian) which contains ten 88,000 lb per hr Yarrow type boilers. The "Bremen" which has almost as much total evaporation contains twenty Yarrow boilers.

The evaporation per square foot of boiler room floor area varies greatly, being as low as 43 lb in the "Manhattan" and 108 lb in the case of the "Alcantara" which has three 77,000 lb per hr Johnson boilers. In the "Normandie" this ratio is 50.7.

The gross overall boiler efficiencies in all the vessels listed are high, ranging from 84.4 for the "Queen of Bermuda," equipped with eight B & W boilers, to 88 per cent in the case of the "Empress of Britain," equipped with eight Yarrow and one Johnson boiler. The respective steam pressures of these two vessels are 390 and 420 lb.

A second group of three German liners, the "Potsdam," "Scharnhorst" and "Gneisenau," equipped with special boilers, is included. The first named has four Benson boilers, each of 61,600 lb per hr rated output operating at 1325-lb pressure, 581 F steam temperature, and each of the other two has four Wagner boilers of approximately 80,000 lb per hr capacity operating at 737-lb pressure and 511 F steam temperature. The evaporation per ton of weight is 1220 lb per hr in the case of the "Potsdam" with Benson boilers compared with 928 lb for the "Alcantara" with Johnson boilers, 394 for the "Normandie," 360 for the "Orion" having six B & W boilers and 211 for the "Queen of Bermuda," also with B & W boilers.

The paper also discussed the Loeffler boiler installation to be made on the "Conte Rosso" (Italian). This unit will operate at 1850-lb pressure, 890 F steam temperature and will replace one of the existing Scotch boilers. This boiler will add about 5000 shaft horsepower and it is estimated that it will improve the fuel economy of the vessel at normal load about 9 per cent.

In conclusion, Admiral Whayman anticipates a future trend toward the use of a smaller number of high-capacity, high-pressure units in marine practice as on shore, and sees the recent installations of Benson, Velox, Wagner and Loeffler boilers on shipboard as a forerunner of the trend.

Extension to Thorpe Station

In contrast to the present trend in the United States of adding central station capacity through superimposing high-pressure, high-temperature units of large capacity on existing low-pressure equipment, British practice appears to favor either the construction of new medium-pressure stations or the extension of present stations through additional condensing units of lesser capacity operating at higher yet moderate pressures, distinct from the older low-pressure equipment but capable of serving it at reduced pressure when occasion demands. An illustration of this trend is to be found in the extension to the Thorpe Power Station at Norwich which is described in the April issue of *Engineering and Boiler House Review*.

This station which was placed in operation ten years ago contained ten Stirling boilers supplying steam at 255 lb 600 F to five turbine units of 55,000 kw combined capacity. The new extension consists of four 120,000 lb per hr bent-tube boilers supplying steam at 675 lb, 875 F to a 30,000-kw two-cylinder tandem turbine-generator, operating condensing.

Unit Power Plants

Because of dissimilar conditions surrounding different plants and customer preference for certain types and makes of component equipment, the idea of a complete power station designed and built by a single manufacturer has never gained wide favor. It is therefore interesting to note in the last issue of the *Brown Boveri Review* (Switzerland) that this company, since its development of the Velox boiler, has embarked upon a plan of furnishing complete power plants including boiler, turbine, auxiliaries and electrical equipment. At present the field of application is limited to the burning of liquid or gaseous fuels owing to the inability of the Velox boiler to burn solid fuels but investigations are now being conducted with the aim of burning solid fuel in this type of steam generator.

As examples of complete power plants furnished by this company there are cited and briefly described the 12,000-kw Haifa station of the Palestine Electric Corporation and the 32,000-kw peak load or standby station for the municipality of Osla, Sweden. There is also included a description of the 15,000-kw station at Wellington, New Zealand, but in this instance the Velox boilers serve two 7500-kw Parsons turbines.

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REVIEW OF NEW BOOKS

Any of the books reviewed on these pages may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Steam Plant Operation

By Everett B. Woodruff and Herbert B. Lammers

The purpose of this book is to present a combination of technical and practical information on the fundamentals of stationary power plant practice and to serve as a reference in preparation for obtaining an operator's license. The authors have had both operating and teaching experience and are thus in a position to understand the point of view and needs of the practical man. The text is arranged for either home study or classroom use.

While the main objectives appear to have been covered, it should be noted that in some respects the text does not encompass some points of latest practice. For instance, while considerable space is devoted quite properly to riveted joints, in view of the prevalence of examination questions dealing with the figuring of such joints, the authors dismiss fusion welding with a brief statement that this is confined to high-pressure work, despite its present wide use for all pressures. Maximum practical air preheat temperatures are given as 300 F and the ratios of air heater to boiler heating surfaces as given are very much lower than obtains in current practice. One fails to find mention of slagging furnaces and the section on stoker firing might well have been amplified to contain more practical information on combustion with various coals.

Despite these short-comings the book should prove very useful for the purpose intended, namely, for license preparation. It contains 368 pages, $5^1/_2 \times 8$ in., bound in cloth. Price $3.00.

Contracts in Engineering

By James Irwin Tucker

This is the third edition. The book is intended to familiarize the engineer with certain legal principles encountered in business transactions, especially a thorough knowledge of contracts and certain rules underlying the writing of specifications. Chapters are included on "real property" and on "corporate and partnership law." Arranged primarily as a textbook for engineering students, the book should prove very useful as a reference for practicing engineers. There are 341 pages, 6×9 in., bound in cloth. Price $4.00.

Power Plant Chemistry

By Augustus H. Gill

Formerly published under the title "Engine Room Chemistry," the present edition has been revised and enlarged, particularly those sections dealing with fuels and their analyses, the analysis of gases of combustion, scale and corrosion and lubricating oils. The treatment is fundamental and elementary, to the extent that the text will be easily comprehensible to the average engineer. As such it is not intended for the man who has more or less specialized in feedwater treatment or other power plant chemistry, but it should be very useful to the operating man. The book contains 228 pages, $5^1/_2 \times 8$ in., bound in cloth. Price $4.00.

Welding Technology and Design

By G. F. P. Fox and F. Bloor

The text is divided into five parts, covering methods of welding and factors determining the use of arc welding; welded joints and strengths; metallurgical and mechanical features; plant and accessories; and applications to structural, electrical, automotive work, shipbuilding and general engineering. It presents a clear introduction to this growing art and the increasing practice of welding. Many useful tables and illustrations are included.

This volume contains 90 pages, $5 \times 7^1/_2$ in., illustrated, bound in cloth. Price $1.50.

High Speed Diesel Engines

By Arthur W. Judge

This is essentially an elementary textbook for engineering students and operators and lays particular stress on automotive and aircraft types. Fundamentals of design appear to be well covered and the descriptive material and illustrations apply particularly to British and Continental types, although the principal American types are also included.

The book contains 347 pages, $5^1/_2 \times 8^1/_2$ in., with cloth binding. Price $6.00.

Steam Turbines

By Edwin F. Church

The author, who is professor of mechanical engineering at the Polytechnic Institute of Brooklyn, prepared the book originally in 1927 as a text for engineering students that would give a short thorough course on steam turbines without treating the subject too exhaustively for classroom use. It deals largely with the application of thermodynamics to turbine design and does not attempt to include operating or test performance nor selection and application. In the second edition (1935), the author has brought the text up to date by eliminating obsolete matter, recalculating the examples in line with the latest steam table values, and by inserting drawings and photographs of recent examples of steam turbine practice.

There are 327 pages, 6×9 in., bound in cloth. Price $3.00.

How to Build up Furnace Efficiency

By Joseph W. Hays

The first edition of this book appeared in 1908 in the form of a small pamphlet presenting the fundamentals of combustion in a simple and unique manner which would be easy to read and readily understood by the practical man. To this end the cartoon type of illustration was employed freely to drive home the idea of proper combustion practice. Since that time the book has been repeatedly revised and enlarged to keep abreast of current practice and that just off the press is the 18th edition. The original method of presentation has been followed throughout the numerous editions, and that it has appealed to the practical man is attested by the fact that over this period 125,000 copies have been put in circulation. Mr. Hays is well known as a combustion engineer and has long preached fuel economy in his writings, lectures and consulting work.

The book contains 559 pages, 5 × 7½ in., and is profusely illustrated, not only with the educational cartoons mentioned but also with many charts, setting drawings and instrument photographs. Price $3.00.

The Surface Condenser

By B. W. Pendred

This is a relatively small book of 144 pages dealing principally with British condenser practice and is based largely on material originally contained in a series of articles that appeared in *The Engineer*. It is essentially a survey of modern practice in that country. Chapters are devoted to the down-flow, radial-flow, inverted and special types, and the condenser installations in some of the more important power stations are described. A concluding chapter discusses pressure, temperature and heat transmission. The subject is well handled and makes both interesting and instructive reading. Price $2.50.

Graphical Solutions

By Charles O. Mackey

Many engineers, especially those concerned with design or operation, find graphical solutions of their every-day problems almost indispensible. Curves and diagrams facilitate study of trends and performance, and charts save much laborious repetition of calculations, with the ever-present chance of committing errors. The subject of graphical presentations is comprehensive enough to fill a sizable treatise, yet a comparatively small part will suffice the needs of the average engineer. The present book appears to meet these requirements. It is based on a course for juniors and seniors that the author has been giving in the School of Mechanical Engineering at Cornell University, and for the greater part requires only a working knowledge of logarithms, algebra and a few principles of plane geometry. Considerable space is devoted to sliding scales, network or intersection charts, alignment charts and to curves based on empirical equations. Typical charts for solving combustion problems, heat transfer, the condensation of water vapor, pumping equations, etc., are discussed.

A perusal of the text should serve to refresh the engineer's mind as to the construction and use of such graphical solutions and at the same time suggest their application to many of the problems encountered in his every-day work.

The book contains 130 pages, 6 × 9 in., well illustrated and bound in cloth. Price $2.50.

Men, Money and Molecules

By William Haynes

This is a dissertation on the growth of the chemical industry, particularly in this country, its many ramifications, the role that it plays in the production of innumerable commonplace commodities and its contribution to the creation of new industries. That the chemical industry is basic to our every-day needs is shown by the fact that even in the darkest period of the depression its production stood at 77 per cent of the 1929 peak, compared with 41 per cent for steel and 36 per cent for automobiles. Appended to the text is a chronological listing of important American chemical developments.

The book is written in a non-technical and entertaining style and is highly informative. It contains 214 pages, 7½ × 5 in., bound in cloth. Price $1.50.

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Power and Fuel at the Ford Plants

Electric power used by the Ford Motor Company in the Detroit area during 1935 amounted to 658,247,947 kwhr, representing a value of more than $5,000,000. Comparison of the 1934 and 1935 figures of electric current generated and consumed in the Rouge Plant at Dearborn is an indication of the company's industrial activities. The 1935 output and consumption exceeded that of 1934 by more than 145,000,000 kwhr.

Of the company's total usage of electricity in the Detroit area, 645,866,091 kwhr was generated and consumed in the Rouge plant; 3,541,000 kwhr was purchased from outside sources for use at the Rouge plant; and the remaining 8,840,856 kwhr was generated and consumed at various Ford factories in the area surrounding Detroit.

In generating the company's requirements of electricity for the year, the equivalent of 747,486 tons of coal was used—enough to fill 19,000 fifty-ton railway coal gondolas. If made up in a single train, they would extend more than 125 miles.

In addition, some of the smaller Ford factories in the Detroit district utilize hydroelectric energy produced by their own generators, to a total of 5,783,251 kwhr for the year.

Included in the company's 1935 fuel consumption in the Detroit area were 3,767,440 gal of oil burned at the Lincoln plant and 1,294,000,000 cu ft of blast furnace and coke oven gas burned in No. 1 power house at the Rouge. Coke breeze equivalent to 103,546 tons of coal was consumed in the Rouge and Highland Park plants.

Total steam produced at the Rouge plant last year was 15,534,035,000 lb, mostly from two 1200-lb pressure boilers and five 250-lb pressure boilers at No. 1 power plant. The rest came from waste-heat boilers located at the open-hearth furnaces, glass plant, cement plant and steel plant soaking pits.

Water used at the Rouge plant during the year totalled more than 291 billion gallons. The requirement per day was approximately 800 million gallons—more than used by the cities of Detroit, Cincinnati and Washington combined.

The power plant is keeping pace with the demands made on it by increased activities in the rest of the factory. An important part of the company's present program of expansion and modernization is proceeding rapidly in No. 1 power house. The new installation includes a 900,000 lb per hr, 1400-lb pressure boiler, a 110,000-kw turbine-generator, and a 15,000-kw turbine-generator, which will soon be placed in service. When the installation is completed, this will be the largest high-pressure steam plant in the world.

Business Items

Plibrico Jointless Firebrick Company, Chicago announce the appointment of **W. R. Wood** as combustion and service engineer in its Chicago office. Mr. Wood was for a period of fifteen years connected with Combustion Engineering Corp. as sales engineer, and subsequently joined the Whiting Corporation, Harvey, Ill., as combustion engineer in its pulverized fuel division. He is well known in the power industry.

Northern Equipment Company, Erie, Pa., has recently made the following additions to its personnel: **F. W. Bunting** and **H. A. Schleider** have joined the Engineering Department as inspection engineers. The former was previously associated with the Radio Corporation of America and the latter with the National Paper Products Co. Also, **C. H. Tate** has been appointed Cleveland district representative with offices in the Hunkin-Conkey Building.

Elgin Softener Corporation has promoted R. J. Murphy, its Pittsburgh district representative to Division Manager with headquarters in the Hippodrome Building, Cleveland. His place in Pittsburgh is being filled by Paul F. Sparrow.

Crane Company, Chicago, announces the appointment of George L. Erwin, Jr., as assistant to the Vice-President in Charge of Sales. Mr. Erwin was formerly General Sales Manager of Kearney & Trecker Corp., Milwaukee, manufacturers of machine tools.

The Edward Valve & Manufacturing Co., East Chicago, Ind., has appointed Lee W. Tremblay as its Philadelphia representative with headquarters in the Witherspoon Building.

Hagan Corporation, Pittsburgh, announces the appointment of Hendrie & Bolthoff Mfg. & Supply Co. of Denver as its representative for the handling of combustion control equipment and as the representative of Hall Laboratories and The Buromin Company in the field of boiler water conditioning.

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